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DCN 81-121-052-14

PSD PERMIT APPLICATION FOR NEW SOURCES TO BE ADDED TO EXISTING AND PREVIOUSLY PERMITTED FACILITIES IN THE PRUDHOE BAY UNIT (PSD IV)

Submitted by:

SOHIO Alaska Petroleum Company
and
ARCO Alaska Incorporated
on behalf of the
Prudhoe Bay Unit Owners

Submitted to:

U.S. Environmental Protection Agency Region X
and the
State of Alaska
Department of Environmental Conservation

Prepared by:

Radian Corporation

30 January 1981

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1.0 EXECUTIVE SUMMARY

Purpose

The purpose of this document is to support an application for a permit to construct additional facilities at the Prudhoe Bay Oil Field in accordance with the requirements of the United States Environmental Protection Agency's (USEPA) Prevention of Significant Deterioration (PSD) regulations which were promulgated August 7, 1980. This document is presented by SOHIO Alaska Petroleum Company (SOHIO) and ARCO Alaska, Incorporated, a division of Atlantic Richfield Company (ARCO), on behalf of the Prudhoe Bay Unit Owners.

Project Description

Additional facilities to be constructed in the Prudhoe Bay Oil Field supplement those facilities described in the Produced Water Injection, Low Pressure Separation, Artificial Lift (PWI/LPS/AL) and the Waterflood PSD permit applications. PSD permits for PWI/LPS/AL and Waterflood applications have subsequently been issued. Because the need for proposed additional facilities reflects the latest engineering design for the facilities covered under the PWI/LPS/AL and Waterflood permits, considerable reference in this document is given to these previous PSD applications.

Project Schedule

Equipment procurement, module fabrication, installation, and startup of the proposed additional facilities will be concurrent with the PWI/LPS/AL and Waterflood projects. Startup of some PWI facilities included in the proposed additions may, however, extend one year beyond the end of the original PWI/LPS/AL project schedule.

Air Pollutant Emission Sources

Atmospheric emissions from the proposed additional facilities will be produced by gas-fired turbines and heaters with approximate total rated capacities of 303 MHP and 250 MM Btu/hr., respectively. These facilities will be located at the three gathering centers, the three flow stations, the Seawater Treatment Plant, and the West Side Injection Plant.

Total potential emissions from the proposed sources are shown below.

Pollutant	Potential Emissions (tons/year)
NO_x	8305
PM	210
CO	1481
SO_2	52
VOC	27

Regulatory Applicability

As indicated in the PSD regulations promulgated on August 7, 1980, the proposed additional facilities constitute a major stationary source and are therefore subject to PSD review. The proposed facilities are also subject to Best Available Control Technology (BACT) for NO_x, CO, PM, SO_2, and VOC.

BACT

A control plan which addresses BACT for each of the above mentioned pollutants has been developed. Because NO_x is the pollutant of most concern in the Prudhoe Bay area, NO_x control received primary attention.

Air Quality Review

The Prudhoe Bay area is an attainment PSD Class II area for all criteria pollutants. The results of the air quality impact analyses show that none of the National Ambient Air Quality Standards (NAAQS) or applicable PSD increments are exceeded as a result of emissions from the proposed additional facilities.

The pollutant of primary concern for this application is NO_2 for which there is an annual NAAQS limit of 100 $\mu g/m^3$. Dispersion modeling results indicate that the highest predicted NO_2 ground level concentration from all sources, including background and existing sources, is about 66 $\mu g/m^3$.

Impacts on Visibility, Soils, Vegetation, and Induced Growth

The impacts on visibility, soils, vegetation, and induced growth resulting from the emissions of the proposed additional facilities will be negligible.

2.0 INTRODUCTION

2.1 Applicant Information

This application is a dual application by SOHIO Alaska Petroleum Company (SOHIO) and ARCO Alaska Incorporated (a Division of Atlantic Richfield Company) (ARCO), operators on behalf of the Prudhoe Bay Unit. Addresses and contacts are as follows:

Owners

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<u>Location of Source</u>

Prudhoe Bay Unit
Prudhoe Bay, Alaska

Approximate Center of Prudhoe Bay Unit:

Latitude:	70° 17' N
Longitude:	148° 34' N
UTM Coordinates:	440.7 East, 7797.2 North

2.2 Source Information

The Prudhoe Bay Unit Owners submitted a PSD permit application in August 1978 and two applications in October 1979 to construct facilities in the Prudhoe Bay Oil Field for the PWI/LPS/AL and Waterflood projects as well as for additional field support facilities. PSD permits (No. PSD-X79-05, PSD-X80-09, and PSD-X81-01) have subsequently been issued for these facilities. Engineering design for each of these projects has progressed since the time of the original application submittals, resulting in the identification of additional facilities not covered under the original PSD applications. Therefore, the facilities described in this application supplement facilities described in the previously mentioned PSD applications. Reference Section 2.2 of the PWI/LPS/AL and Waterflood applications for additional source information.

The proposed facilities consist of various turbines and heaters located at the three gathering centers, the three flow stations, the Seawater Treatment Plant, and the West Side Seawater Injection Plant. The turbines and heaters, having an approximate total rated capacity of 303 MHP and 250 MMBtu/hr, respectively, will be fired by natural gas.

In accordance with Section 165 of the Clean Air Act, the Prudhoe Bay Unit Operators are applying to EPA Region X for a permit which will certify that the new facilities will be consistent with the Act's rules for Prevention of Significant Deterioration (PSD) of air quality and that they will implement Best Available Control Technology (BACT). This document is intended to support the granting of such a permit.

3.0 DESCRIPTION OF PROPOSED FACILITIES

3.1 Equipment Description

Atmospheric emissions will be generated by additional gas-fired turbine capacity at the three gathering centers, the three flow stations, the Seawater Treatment Plant, and the West Side Injection Plant as well as by additional gas-fired heaters at Flow Stations 1 and 3. Table 3-1 lists the proposed emission sources associated with this project. These sources represent current engineering design capacity requirements. The proposed sources represent supplemental turbine and heater capacity for the previously approved PWI/LPS/AL and Waterflood Projects. Detailed equipment descriptions can be found in Section 3.0 of the Unit Owners' PWI/LPS/AL and Waterflood applications and are similar for the proposed sources. The Unit Operators may exercise options in selecting the individual turbine and heater unit sizes to achieve the desired installed capacity at each location; however, the worst-case assumptions used for emissions calculations and modeling shown in Section 3.3 will not be exceeded.

3.2 Project Schedule

The PWI/LPS/AL and Waterflood Projects are maintaining a milestone schedule basically as outlined in the original applications. The only exception to that schedule due to the proposed facilities is a one year extension of the startup date for some PWI facilities described in this application. All proposed turbines and heaters are assumed to operate continuously and should be permitted for such operation.

PSD IV

TABLE 3-1

PROPOSED FACILITIES SOURCE LIST

Location	Description
GC-1	2-7.5 MHP Turbines
GC-1	35 MHP Turbine Capacity
GC-2	3-7.5 MHP Turbines
GC-2	45 MHP Turbine Capacity
GC-3	1-7.5 MHP Turbine Capacity
GC-3	60 MHP Turbine Capacity
West Injection Plant	25 MHP Turbine Capacity
FS-1	1-5 MHP Turbine
FS-1	125 MM Btu/hr. Heater Capacity
FS-1	36 MHP Turbine Capacity
FS-2	2-5 MHP Turbines
FS-3	2-5 MHP Turbines
FS-3	125 MM Btu/hr. Heater Capacity
Seawater Treatment Plant	8-4 MHP Turbines

3.3 New Source Emissions and Operating Parameters

3.3.1 Methodology for Gas-Fired Turbines

The method used to calculate potential emissions for gas turbines is based on the fuel gas composition or on AP-42 emission factors. A typical fuel gas composition is presented in Appendix B.

Nitrogen Oxides (NO_x)

Because of extremely high combustion temperatures, oxides of nitrogen (NO_x) are emitted in the greatest quantity from the turbines, but other pollutants will also be emitted. Table 3-2 presents potential emissions from these turbines. Worst-case stack characteristics for these units are presented in Table 3-3.

Potential emissions of nitrogen oxides are based on promulgated New Source Performance Standards for Stationary Gas Turbines (NSPS) (Federal Register, Vol. 44, September 10, 1979, p. 52798). Combustion calculations are performed on the fuel gas analysis (see Appendix B) with the result that one mole of fuel yields 31.90 moles of flue gas at 15 percent excess O_2 on a dry basis at 70°F. Operating parameters for gas turbines were obtained from manufacturers' data and fuel consumption rates were determined from these parameters. NO_x (as NO_2) emissions were then calculated at 150 ppmv of flue gas as specified in the NSPS. The equations used in performing calculations are shown in Appendix B.

TABLE 3-2
PROPOSED SOURCE POTENTIAL EMISSIONS AND STACK CHARACTERISTICS WORST IMPACT SCENARIO

Map ID	Description	East	North	Potential Emissions					Stack Characteristics			
				NO_x (g/s)	CO (g/s)	TSP (g/s)	SO_2 (g/s)	HC (g/s)	Height (m)	Diameter (m)	Velocity (m/sec)	Temperature (°K)
GC-1	2-7.5 MHP turbines	434.70	7800.95	11.53	2.08	0.28	0.068	0.38	22.2	1.16	31.4	450
GC-1	35 MHP turbine capacity	434.65	7801.00	26.90	4.85	0.66	0.159	0.88	22.2	1.98	33.2	450
GC-2	3-7.5 MHP turbines	430.05	7801.70	17.29	3.12	0.43	0.102	0.57	22.2	1.16	31.4	450
GC-2	45 MHP turbine capacity	430.10	7801.75	34.59	6.24	0.85	0.204	1.13	22.2	1.98	33.2	450
GC-3	1-7.5 MHP turbine	436.75	7798.50	5.76	1.04	0.14	0.034	0.19	22.2	1.16	31.4	450
GC-3	60 MHP turbine capacity	436.80	7798.55	46.12	8.32	1.13	0.272	1.51	22.2	1.98	33.2	450
IPW	25 MHP turbine capacity	435.00	7800.70	19.22	3.47	0.47	0.113	0.63	22.2	1.98	33.2	450
FS-1	1-5 MHP turbine	446.00	7795.15	3.84	0.69	0.09	0.023	0.13	22.2	1.16	31.4	450
FS-1	125 MM Btu/hr heater capacity	445.90	7795.10	3.02	0.29	0.17	0.057	0.05	22.2	0.91	14.4	450
FS-1	36 MHP turbine capacity	446.10	7795.30	27.67	4.99	0.68	0.163	0.91	22.2	1.98	33.2	450
FS-2	2-5 MHP turbines	449.45	7795.40	7.69	1.39	0.19	0.045	0.25	22.2	1.16	31.4	450
FS-3	2-5 MHP turbines	440.65	7795.70	7.69	1.39	0.19	0.045	0.25	22.2	1.16	31.4	450
FS-3	125 MM Btu/hr heater capacity	440.65	7795.60	3.02	0.29	0.17	0.057	0.05	22.2	0.91	14.4	450
SWTP	8-4 MHP turbines	443.00	7810.10	24.60	4.44	0.60	0.145	0.81	22.2	0.76	29.0	450
	TOTAL EMISSIONS			238.9	42.60	6.05	1.490	7.74				

*IPW - Injection Plant - West Side
**SWTP - Seawater Treatment Plant

TABLE 3-3

STACK PARAMETERS AND OPERATING CONDITIONS

ASSUMED FOR SOURCES MODELED

Map ID	Description	Modeled Stack Characteristic Assumptions
GC-1	2-7.5 MHP turbines[1]	5 MHP turbines w/WHR[5]
GC-1	35 MHP turbine capacity[2]	22.6 MHP turbine w/WHR
GC-2	3-7.5 MHP turbines[1]	5 MHP turbine w/WHR
GC-2	45 MHP turbine capacity[2]	22.6 MHP turbine w/WHR
GC-3	1-7.5 MHP turbine[1]	5 MHP turbine w/WHR
GC-3	60 MHP turbine capacity[2]	22.6 MHP turbine w/WHR
IPW	25 MHP turbine capacity[2]	22.6 MHP turbine w/WHR
FS-1	1-5 MHP turbine[1]	5 MHP turbine w/WHR
FS-1	125 MM Btu/hr heater capacity[3]	25 MM Btu/hr heater w/WHR
FS-1	36 MHP turbine capacity[2]	22.6 MHP turbine w/WHR
FS-1	2-5 MHP turbines[1]	5 MHP turbine w/WHR
FS-3	2-5 MHP turbines[1]	5 MHP turbine w/WHR
FS-3	125 MM Btu/hr heater capacity[3]	25 MM Btu/hr heater w/WHR
SWTP	8-4 MHP turbines[4]	2 MHP turbine w/WHR

[1]This total capacity will be attained with multiple turbines with individual capacities ranging from 5 to 7.5 MHP.

[2]This total capacity will be attained with multiple turbines with individual capacities ranging from 22.6 to 36 MHP.

[3]This total capacity will be attained with multiple heaters with individual capacities ranging from 25 to 125 MM Btu/hr.

[4]This total capacity will be attained with multiple turbines with individual capacities ranging from 2 to 4 MHP.

[5]WHR - Waste Heat Recovery

Hydrocarbons (HC)

Potential emissions of hydrocarbons (HC), and carbon monoxide (CO) are based on AP-42 emission factors for gas turbine compressor engines, Table 3.3.2-1 (EPA, AP-42, August 1977, p. 149). HC emissions are given as total hydrocarbons and nonvolatile organic compounds (VOC) emissions should only comprise about 5-10 percent of this total (EPA, AP-42, August 1977, p. 149). The emission calculations are presented in Appendix B.

Particulate Matter (PM)

Emission factors for particulates from gas turbines are listed as not available in Table 3.3.2-1 of AP-42. Consequently, the factor from Table 3.3.1-2, composite emission factors for electric utility gas turbines was used (EPA, AP-42, August 1977, p. 146).

Sulfur Dioxide (SO_2)

The emission factor used is based on an estimated fuel gas composition of 20 ppm H_2S, a maximum heat rate of 9800 Btu/hp-hr and conditions of 70°F and 1 atmosphere. Potential emissions are listed in Table 3-2. Worst-case stack characteristic assumptions are presented in Table 3-3. The emission rate calculations are presented in Appendix B.

3.3.2 Methodology for Gas-Fired Heaters

The potential emissions of NO_x, PM, CO, and HC from gas-fired heaters are based on AP-42 emission factors for natural gas combustion sources, Table 1.4-1 (EPA, AP-42, August 1977, p. 39). The emissions calculations are presented in Appendix B.

The potential emissions and worst-case stack characteristics are reported in Table 3-2 and Table 3-3, respectively.

Sulfur Dioxide (SO_2)

The sulfur dioxide emissions calculations are based on an estimated fuel gas composition of 20 ppm H_2S and a lower heating value of the Prudhoe Bay gas of 914 Btu/scf (70°F, 1 atmosphere). Worst-case stack characteristics are shown in Table 3-2. The emission rate calculation is shown in Appendix B.

3.3.3 Building Dimensions and Source Spacings

The stack heights of the proposed source additions will be a minimum of three meters greater than the height of their adjacent buildings. This criteria applies to all Prudhoe Bay Unit Owner facilities covered under previous PSD permits.

The greatest concentration of existing, previously permitted, and proposed sources is at the gathering centers and flow stations. Therefore source spacing assumptions were used only at these facilities. For all other Prudhoe Bay Unit facilities (i.e., Central Compressor Plant, Central Power Station, West Injection Plant, East Injection Plant, and the Seawater Treatment Plant) colocated sources were assumed.

The plot plan shown in Figure 3-1 is used to illustrate the location of existing as well as future planned facilities at a typical gathering center (flow stations serve the same basic function as the gathering centers). Facilities are dispersed over an area of approximately 40,000 to 80,000 square

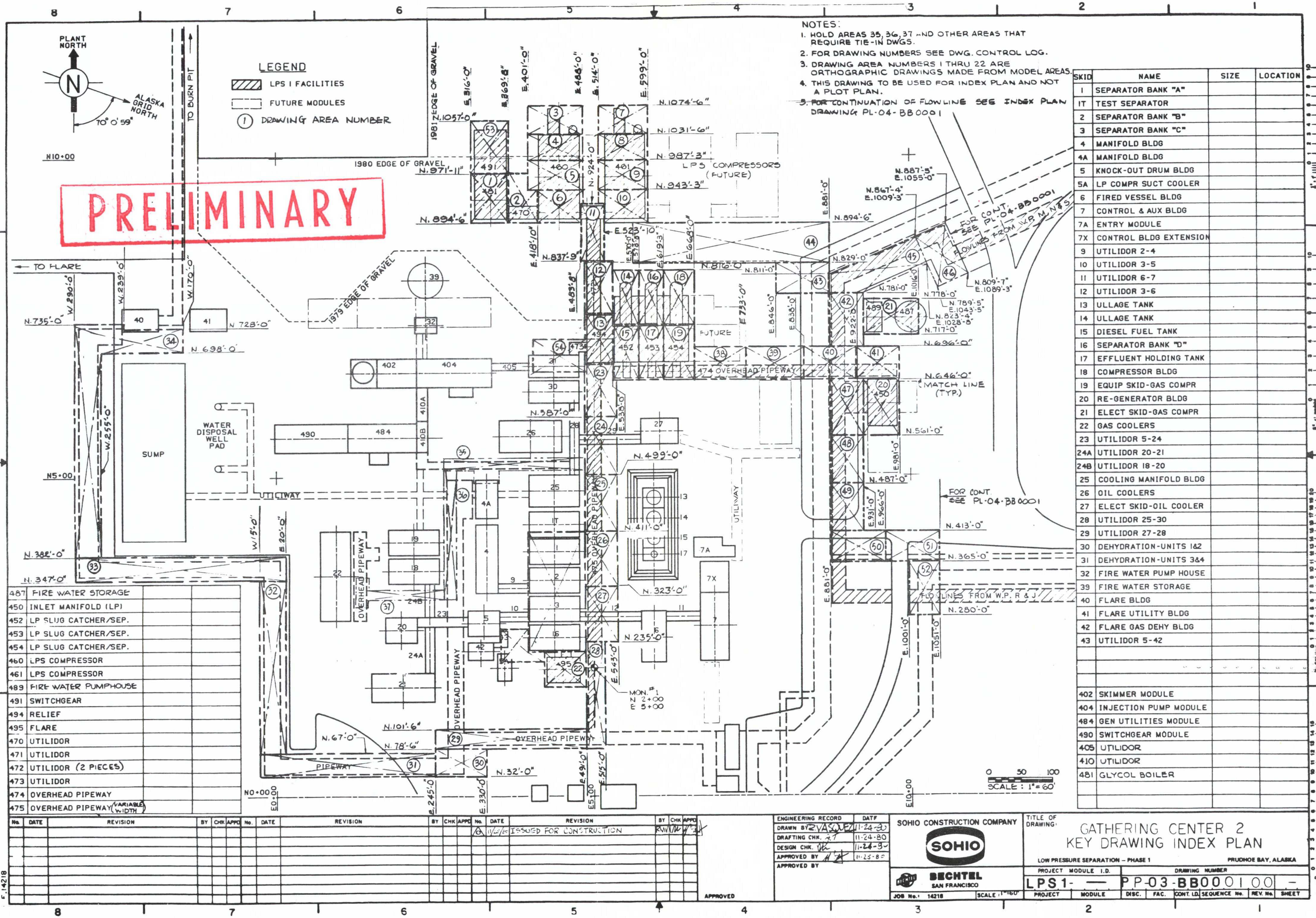

Figure 3-1. Gathering Center 2 Key Drawing Index Plan

meters. For modeling purposes, each source listed in the emissions inventory was spaced randomly between 50 and 100 meters apart within a total grid box of 40,000 square meters. The center of the grid box has the approximate UTM coordinates of the center of the specific facility (i.e., gathering center or flow station). Figure 3-2 schematically shows the source grid spacing. A random source spacing was used because the location, number, and sizes of specific future modules is constantly changing as the design process continues. In the preliminary plan shown in Figure 3-1 turbine and heater sources are located in Skids 6, 20, 21 (existing); 481, 491, 460, 461 (LPS facilities), and 402, 404, 484, 490 (PWI facilities). Because it was recognized that individual stacks from similar sources may actually be built as close as 10 meters apart, (e.g., a bank of heaters) the emissions inventory colocates these sources into discrete groups. This should provide adequate conservatism for multiple sources within close proximity of each other. The above described source spacing approach was used to provide a more realistic prediction of ground level impacts.

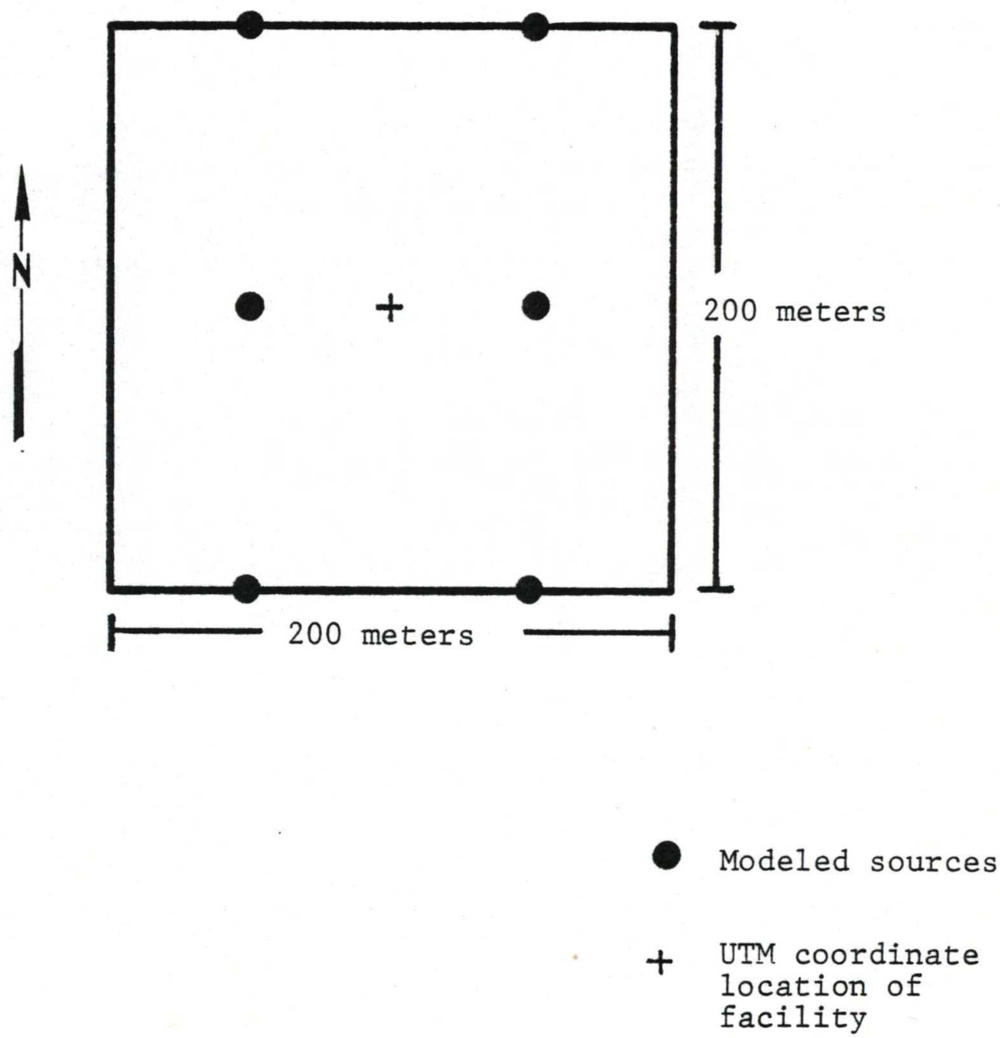

Figure 3-2. Typical Stationary Source Grid

4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 Site Topography and Land Use

The land use of the Prudhoe Bay area is predominantly rural, as determined by the urban/rural classification scheme described in the proposed Revisions to the Guideline on Air Quality Models (EPA, 1980). Therefore use of rural modeling techniques is appropriate for the region.

A detailed description of the topography and land use of the Prudhoe Bay area is described in Section 4.1 of the Unit Owners' Waterflood Application (1979).

4.2 Soils and Vegetation

A description of the soil characteristics and vegetation communities in the Prudhoe Bay area is presented in Section 9.0 of the Unit Owners' Waterflood Application (1979).

4.3 Climate

The general climate of the Prudhoe Bay area including patterns of precipitation, snowfall, temperature, fogging, and icing are best determined from an examination of National Climatic Center and National Weather Service data sources. Such a description is presented in Section 4.2 of the Unit Owners' Waterflood Application (1979).

A one year air quality and meteorological monitoring program was conducted in the Prudhoe Bay area between April 1, 1979 and March 31, 1980. Wind direction, wind speed, as well as stability patterns and distributions have been determined from data collected during this program at the 10-meter level of the two monitoring stations and at the instrumented tower. This program is described in more detail in Section 4.4 of this application.

The annual wind roses for Drill Pad A and Drill Site 9 (based on one year of data) for Prudhoe Bay are presented in Figures 4-1 and 4-2.

The most frequent wind directions observed at each of the Prudhoe Bay monitoring sites were from the east and east-northeast (about 40 percent of the time) with a secondary maximum from the west-southwest (about 10 to 15 percent of the time). The annual wind roses look similar to the 1976 wind rose for nearby Deadhorse Airport. (The Deadhorse wind rose is presented in Section 4.0 of the Unit Owner's Waterflood Application.) The average wind direction is from the east to east-northeast for most of the year except for November through February when the flow changes to a direction from the southwest to west-southwest.

The annual average wind speed was 13.3 miles per hour (mph) at Well Pad A and 13.5 mph at Drill Site 9 for the monitoring period. During the same period, Point Barrow reported an average speed of 13.2 mph. The average speed for Barter Island could not be computed because of missing wind data. In general, the monthly average wind speeds showed the same trends at all of the sites. The monthly averages show consistently high speeds, over 10 mph, but they also show a fair amount of geographic variability, especially in January and December.

Another comparison can be made with 1976 wind data from the nearby Deadhorse Airport. For that year the average speed was 12.8 mph which approximates the Well Pad A and Drill Site 9 speeds (13.3 and 13.5 mph) for 1979-1980.

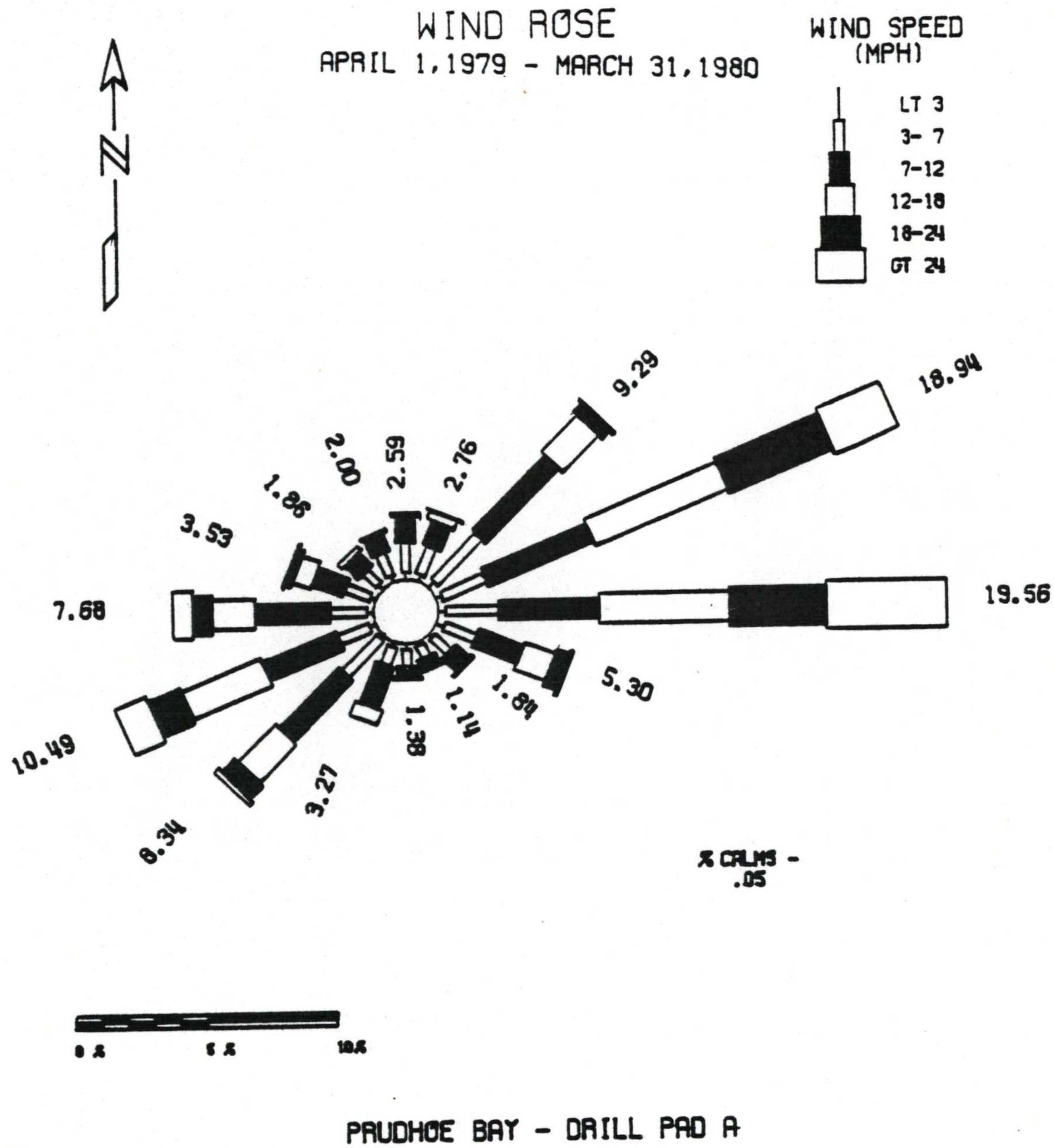
WIND ROSE
APRIL 1,1979 - MARCH 31,1980
WIND SPEED
(MPH)
LT 3
3- 7
7-12
12-18
18-24
GT 24
N
9.29
18.94
2.00
2.59
2.76
1.86
3.53
7.68
19.56
5.30
1.84
1.14
1.38
10.49
3.27
8.34
% CALMS -
.05
0 %
5 %
10%
PRUDHOE BAY - DRILL PAD A

Figure 4-1

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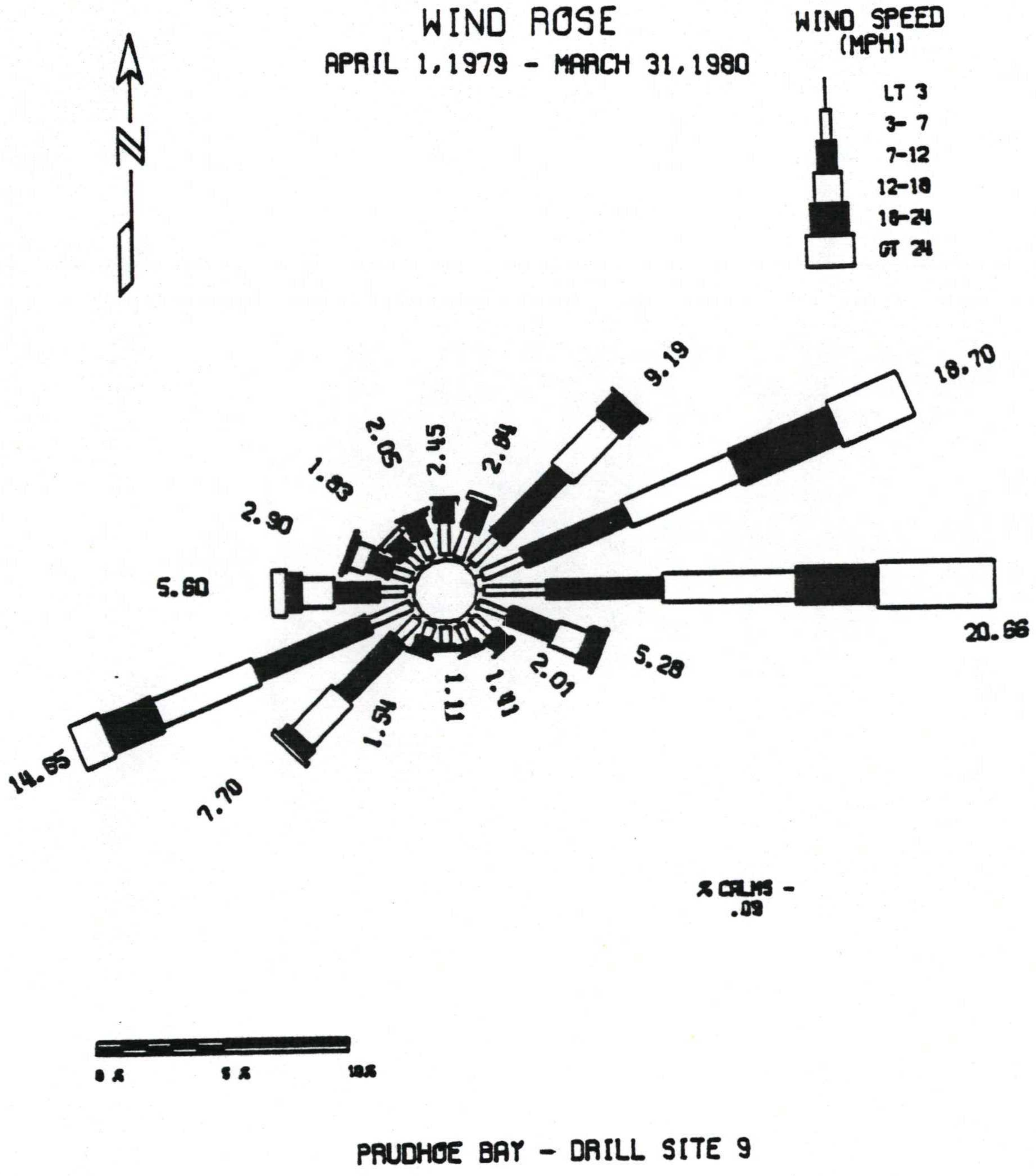

Figure 4-2

The annual frequency distribution of the six stability classes for Prudhoe Bay are presented in Table 4-1. The processing of the on-site meteorological data to generate the annual frequency distribution is described in Appendix C. The mean wind speed associated with each stability class is also given. This table indicates that neutral stability class conditions occur about 61 percent of the time at Prudhoe Bay. According to Pasquill's standard method for determining stability classes, neutral conditions generally result from moderate to strong winds and cloudy conditions (National Climatic Center, 1958 to 1964). Seasonal and annual joint frequency distributions for wind speed, wind direction, and stability class, calculated from the Prudhoe Bay data, are presented in Appendix E.

TABLE 4-1

ANNUAL FREQUENCY DISTRIBUTION OF PASQUILL STABILITY CLASSES AND WIND SPEEDS AT PRUDHOE BAY

Stability Class	Definition	Annual Frequency (%)	Average Wind Speed (mph)
A	Extremely Unstable	0.76	5.5
B	Unstable	0.63	5.3
C	Slightly Unstable	1.18	5.1
D	Neutral	61.16	14.8
E	Slightly Stable	19.80	6.4
F	Stable to Extremely Stable	16.46	6.9

Source: Radian Corporation, Air Quality and Meteorological Monitoring Study at Prudhoe Bay, Alaska (April 1, 1979 to March 31, 1980) October 1980.

4.4 Existing Air Quality

Determination of the impact of emissions from all sources (including the proposed facilities) in the Prudhoe Bay area on the National Ambient Air Quality Standards (NAAQS) requires a determination of the existing air quality of the area. This determination also illustrates the current status of compliance with the National Ambient Air Quality Standards.

Background levels, estimated from current air quality monitoring data can be added to concentrations predicted for all the sources to predict total air quality impacts. For the purposes of this document, the term "background" refers to the contributions to total air quality from all anthropogenic and natural sources outside of or upwind from the Prudhoe Bay area.

For the purposes of the PSD study, air quality data collected at two monitoring sites in the Prudhoe Bay area were used to characterize existing and background air quality levels. Beginning on April 1, 1979 until March 31, 1980, the Prudhoe Bay area operators conducted a one-year air quality and meteorological monitoring program. The network consisted of two remote sites designed to collect both air quality and meteorological parameters and a 200-foot communications tower instrumented with meteorological sensors. The remote monitors were located at Drill Site 9 and Well Pad A and the instrumented tower was located at the SOHIO Base Operating Camp (Figure 4-3).

The following air quality and meteorological parameters were collected at each remote site:

1. Oxides of Nitrogen (NO_x)
2. Nitric Oxide (NO)
3. Nitrogen Dioxide (NO_2)

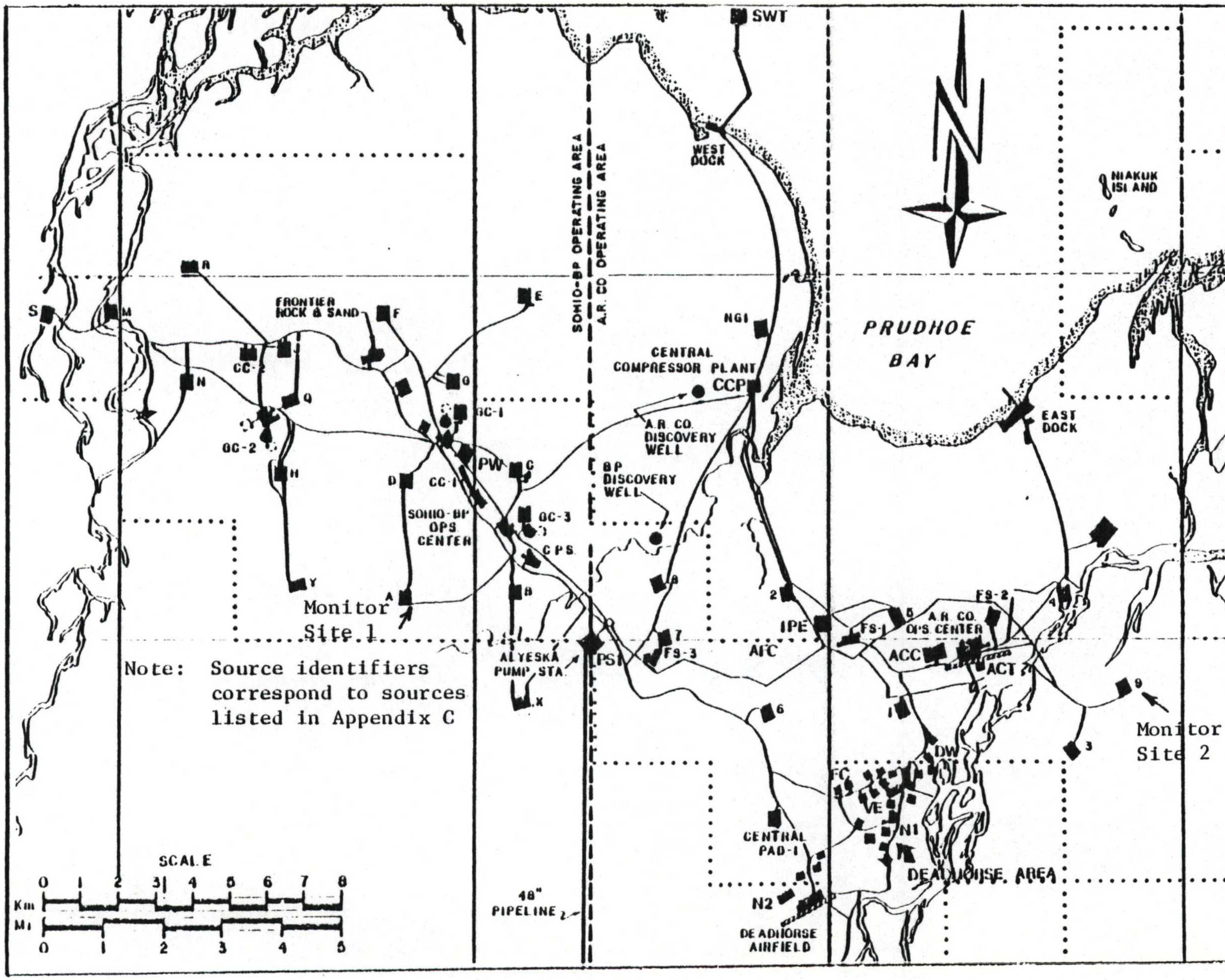

Figure 4-3. Location of Air Quality Monitors

4. Sulfur Dioxide (SO_2)
5. Ozone (O_3)
6. Carbon Monoxide (CO)
7. Total Hydrocarbons (THC)
8. Methane (CH_4)
9. Non-Methane Hydrocarbons ($THC-CH_4$)
10. Wind Speed (33 feet)
11. Wind Direction (33 feet)
12. Temperature (33 feet)
13. Total Suspended Particulates (TSP)

In addition, precipitation and visibility were measured at Drill Site 9 (Site 2 in Figure 4-3), the upwind site. Temperature layering heights and wind profiles were measured at Well Pad A (Site 1 in Figure 4-3), the downwind site, using an ECHOSONDE® acoustic sounder system. This ECHOSONDE® temperature structure data was used in estimating on-site mixing heights for the Prudhoe Bay area.

The following meteorological parameters were monitored at the 60 meter communications tower site:

Temperature	33-foot level
Temperature	33 - 200-foot level
Wind Speed	146-foot level
Wind Direction	146-foot level
Wind Speed	200-foot level
Wind Direction	200-foot level
Wind Direction Horizontal Standard Deviation	200-foot level

To support the monitoring activities, a monitoring plan entitled Ambient Air Quality and Meteorological Monitoring Plan for Prudhoe Bay, Alaska was submitted to EPA Region X and the Alaska DEC in late 1978. This monitoring program is being used to satisfy PSD-related monitoring requirements. The monitoring plan demonstrated that all siting, operating, quality assurance, and data validation procedures employed in the network operation corresponded to guidelines established by the Environmental Protection Agency.

An annual monitoring report entitled Air Quality Meteorological Monitoring Study For Prudhoe Bay, Alaska will be submitted separate of this application. This report covers the period from April 1, 1979 until March 31, 1980 and presents a summary of air quality and meteorological parameters.

Table 4-2 reports maximum and mean levels of NO_2, TSP, SO_2, CO, and ozone (O_3) measured during the 12 month monitoring period. Examination of this table shows that measured levels for all pollutants are well below those concentrations allowed by the National Ambient Air Quality Standards. The results of the monitoring program as presented in this table support the current designation of the Prudhoe Bay area as being in attainment of the NAAQS for criteria pollutants. Even if the highest pollutant levels measured during the monitoring program were added to the predicted levels of NO_2, TSP, SO_2, CO, and O_3 resulting from sources in the Prudhoe Bay area the NAAQS would not be exceeded.

Background pollutant levels for use in determining total air quality impacts on NAAQS were estimated from the data

TABLE 4-2

MEASURED POLLUTANT LEVELS ($\mu g/m^3$)

IN THE PRUDHOE BAY AREA*

Pollutant	Monitor Location: Drill Site 9	Monitor Location: Well Pad A	National Ambient Air Quality Standards: Primary	National Ambient Air Quality Standards: Secondary
NO_2				
Arithmetic Mean*	3.5	4.0	100 (Annual)	100 (Annual)
TSP				
Geometric Mean*	6.7	11.4	75 (Annual)	60 (Annual)
24 Hour Maximum+	64	119	260	150
SO_2				
Arithmetic Mean*	0.4	0.5	80 (Annual)	---
24 Hour Maximum+	9.5	9.3	365	---
3 Hour Maximum+	13.0	25.3	---	1300
CO				
8 Hour Maximum+	946	856	10,000	10,000
1 Hour Maximum+	3430	3120	40,000	40,000
O_3				
1 Hour Maximum++	113	113	235	235

*Period of Record (4/1/79 - 3/31/80)

+Not to be exceeded more than once per year.

++Ozone standard is attained if the expected number of days per calendar year with maximum hourly average concentrations is $\leq$one.

collected during the Prudhoe Bay monitoring program. In order to eliminate the influence of existing Prudhoe Bay area sources on the monitors, only those periods during which the monitors were upwind of all Prudhoe Bay sources were selected for use in the background estimation. For each pollutant, the mean of all concentrations measured during the selected periods was chosen as the background applicable for all averaging times with the exception that it is unreasonable to expect the mean background monitored concentration to exceed the mean annual monitored concentration. It was assumed that measurements occurring during periods of east-northeast winds at Drill Site 9 and west-southwest winds at Well Pad A would be representative of background conditions in the Prudhoe Bay area.

Based on these assumptions and methods, background concentrations were estimated for the two monitor sites and are shown in Table 4-3.

TABLE 4-3

ESTIMATED BACKGROUND AND MONITORED POLLUTANT LEVELS

	Pollutant Concentrations ($\mu g/m^3$)				
	NO_2	TSP	SO_2	CO	O_3
Annual Monitored Values					
For Source Segregation					
East-Northeasterly Winds - Drill Site 9	1	15	*	100	51
West-Southwesterly Winds - Well Pad A	2	5	*	190	51
Total Annual Mean					
Well Pad A	4	11	*	171	48
Drill Site 9	4	7	*	133	51
Estimated Background Levels**	2	11	--	171	51

*Below detectability limit of instrument.

**Background levels estimated by using monitored data as indicated by encircled values in table.

4.5 Existing, Permitted, and Proposed Emissions From Other Sources

Inventories of SO_2, CO, NO_x, PM and hydrocarbon emissions from other existing and proposed sources were compiled for use in performing the air quality impact analyses. Appendix A presents the inventories for these sources as well as the inventory for the proposed Prudhoe Bay Unit additions.

The inventories for other sources were separated into the following groups:

Group 1. Existing Sources

Group 2. Unit Owners' PSD I Sources (Permit No. PSD-X79-05)

Group 3. Unit Owners' PWI/LPS/AL sources (Permit No. PSD-X80-09)

Group 4. Unit Owners' Waterflood Sources (Permit No. PSD-X81-01)

Group 5. Unit Owners' Additional Sources (1980 Equipment Exchange Analysis)

Group 6. Proposed Non-Unit Sources (1981 Northwest Alaska Pipeline Company Application)

The inventory for Group 1 sources is identical to that reported in the Unit Owners' Waterflood Application. This group of sources is comprised of existing oil field sources in the Prudhoe Bay Unit and existing Deadhorse area sources.

The inventory Group 2 is similar to that reported for sources proposed in the Unit Owners' PSD I Application. This inventory, however, does not include sources deleted from Group 2 as a result of the Unit Owners' 1980 Equipment Exchange Analysis.

The inventories for Groups 3 and 4 are based on the emission inventories reported in the PWI/LPS/AL Application (1980 Permit) and Waterflood Application. These inventories, however, include all changes in assumed stack parameters covered in Case 2 of the modeling analysis reported in Radian Corporation's January 14, 1980 technical document prepared for the Prudhoe Bay Unit Owners and presented to EPA Region X. These changes are also reflected in the Unit Owners' 1980 Equipment Exchange analysis.

It should be noted that turbines included in the Unit Owners' Waterflood Application, with capacities greater than 16 MPH, may be installed as combinations of individual turbine units with ratings ranging from 16 to 36 MPH. Allowance for this range of Waterflood turbine sizes was not specifically requested in any of the previous permit applications or analyses presented to EPA Region X. However, previous modeling analyses presented by the Unit Owners to EPA Region X demonstrate that increasing the size of turbine units without increasing total turbine capacity or total pollutant emissions would not result in increased predicted ground level concentrations.

The Group 5 inventory includes all additional sources reported in the Unit Owners 1980 equipment exchange analysis.

The SO_2 emissions for all gas-fired unit sources in Groups 1 through 5 have been recalculated based upon an estimated H_2S content of the field fuel gas of 20 ppm (Appendix B).

The inventory for Group 6 consists of those sources included in the PSD permit application prepared by the R. M. Parsons Company for the Northwest Alaska Pipeline Company's proposed gas conditioning plant. This application is being submitted by R. M. Parsons Company at about the same time as the Unit Owners 1981 permit application. The gas conditioning plant sources are included in the impact analyses to facilitate completeness determination for the Unit Owners' application.

The methodology for determining the spacing of individual emission points within the Prudhoe Bay Unit facilities is discussed in Section 3.3.

4.6 References for Section 4

Radian Corporation, Ambient Air Quality and Meteorological Monitoring Plan for Prudhoe Bay, Alaska, 1978.

Radian Corporation, Ambient Air Quality and Meteorological Monitoring Study for Prudhoe Bay, Alaska, 1980.

U.S. Environmental Protection Agency, Guideline on Air Quality Models -- Proposed Revision, 1980, Office of Air Quality Planning and Standards.

5.0 BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

Prevention of Significant Deterioration (PSD) Regulations promulgated by the USEPA on August 7, 1980 state that a project must apply Best Available Control Technology (BACT) to each pollutant regulated under the Clean Air Act for which a proposed facility emits a "significant" amount. "Significant" in terms of net emissions increase or potential to emit means an emission rate for a proposed source that would equal or exceed the values shown in Table 5-1. For comparison, the total potential emissions for the proposed facilities are also shown in Table 5-1.

Net emission increases for CO, NO_x, SO_2, and PM exceed the significant levels for the proposed new sources. Although volatile organic compound (VOC) emissions for the proposed sources are not significant when added to the VOC emissions from the PWI/LPS/AL (75 TPY) and Waterflood (15 TPY) applications, the total of 117 TPY VOC is in excess of the significant level. It was necessary to consider VOC emissions from sources proposed in the PWI/LPS/AL and Waterflood projects because their VOC emissions were not subject to BACT under the 1978 PSD regulations. Therefore, BACT will be applied to control emissions of CO, NO_x, SO_2, PM, and VOC for the proposed facilities.

In a manner consistent with national and EPA Region X guidelines, an analysis has been performed to determine BACT for the proposed facilities. Reference Section 5 of the Unit Owner's PWI/LPS/AL and Waterflood applications for the detailed BACT determination. To supplement the BACT determinations found in the above referenced PSD applications, BACT as described in the Unit Owner's PWI/LPS/AL and Waterflood permits (Permit Nos. PSD-X80-01 and PSD-X-81-01) will be applied to the gas-fired turbines

TABLE 5-1

NET EMISSIONS INCREASES AND SIGNIFICANT LEVELS FOR ADDITIONAL PRUDHOE BAY UNIT SOURCES

Pollutant	Net Emissions Increase (t/y)	Significant Level (t/y)
CO	1481	100
NO_x	8305	40
SO_2	52	40
PM	210	25
HC	269	*
VOC	27	40**

*No significant levels are defined in the August 7, 1980 PSD regulations for total hydrocarbons.

**VOC (Volatile organic compound) emissions were conservatively assumed to be 10 percent of total hydrocarbon emissions.

and heaters proposed in this application. These BACT conditions are summarized below:

Turbines

Natural gas firing and the use of dry (internal combustion) controls.

Heaters

1. Natural gas firing.

2. For process heaters with a rated capacity greater than 43 MM Btu/hr low NO_x burners will be installed.

3. For process heaters with a rated capacity greater than 43 MM Btu/hr. The levels of CO or O_2 in the combustion flue gas will be monitored on a continuous or periodic basis as an indicator of good combustion.

6.0 AIR QUALITY IMPACT ANALYSIS

6.1 Analysis Methodology

Atmospheric dispersion modeling techniques, recommended in the 1980 proposed EPA modeling guidelines were used to predict the total air quality impacts of the proposed equipment additions to the Prudhoe Bay unit. Annual modeling was performed using the rural version of the Industrial Source Complex Long Term (ISCLT) model (Bowers, et al., 1979), and short-term modeling (24-hour averaging times or less) was performed using the rural version of the Industrial Source Complex Short Term (ISCST) model. In the application of all these models the building wake effects option was used.

To expedite the permit application review, the ISCLT and ISCST models were used, as required by EPA Region X. These models, however, have not been subjected to comprehensive technical review and "debugging". In addition, their applicability for use in the Prudhoe Bay area for modeling turbines and heaters, especially with the building wake effects option included, has not been conclusively demonstrated.

For carbon monoxide, the proposed EPA short-term screening model, PTPLU, was applied, with resulting calculated ambient impacts so low that more detailed modeling applications were considered to be unnecessary. Because of the very low monitored concentrations of ozone in the area, and low sun angles, photochemical modeling of non-methane hydrocarbon emissions was considered to be inappropriate. Therefore, the potential impacts of hydrocarbon emissions on ozone characteristics were evaluated using a reverse rollback estimation technique applied to measured ozone levels.

The ISCLT model was used to estimate the impacts of the proposed sources alone and in conjunction with existing and permitted and other proposed sources, on annual average concentrations of NO_2, SO_2, and TSP. ISCLT modeling results for NO_x and measured ozone concentrations were examined with the ozone limiting method (described in the proposed 1980 EPA modeling guidelines) to determine maximum NO_2 levels. The ISCST model was used for calculations of 3-hour and 24-hour SO_2 concentrations and 24-hour TSP concentrations. Prudhoe Bay ambient air monitoring network data were used to estimate the contributions to total ambient short-term and long-term concentrations from background sources (Section 4.4).

Meteorological data used in the ISC modeling was that obtained from the Prudhoe Bay area PSD monitoring network, as described in Section 4.3. For annual modeling, a joint frequency distribution of wind speed, wind direction, and stability class for a one-year period (STAR deck) was used as meteorological input. The stability classes were calculated using the modified sigma theta method (Proposed Revisions to EPA Guidelines on Air Quality Models, October 1980). In the application of this method, stable conditions occurring at wind speeds greater than 11 knots were converted to stability Class D. For short-term modeling, pre-processed hourly meteorological data from the Prudhoe Bay monitoring network were input to the ISCST model. Meteorological data processing and dispersion model features are described in more detail in Appendices C and D. The representativenss of the Prudhoe Bay meteorological data is discussed in Appendix F.

Emissions sources listed in Appendix A were modeled in the annual ISC analysis for NO_x. For all sources except the "Non-Unit" sources of Case 1, building heights and widths associated with each stack were also input to the model. No building dimensions were input for the existing "Non-Unit" sources because no information was available to specify or estimate building geometry.

6.2 Initial Screening

6.2.1 Annual

Potential emissions of SO_2, NO_x, and PM from the proposed Prudhoe Bay Unit sources were modeled with the rural mode of ISCLT to determine the potential for significant impacts for the different pollutants. The results of this modeling analysis are presented in Table 6-1. The existing, permitted, and proposed emissions sources in the Prudhoe Bay area were identified with distinct facility locations. SO_2, NO_x, and PM emissions were totaled for each of these facilities and the facilities were ranked according to the total emissions. Receptor grids were constructed around the eight facilities with the maximum pollutant emissions. An 8 x 5 grid with a 0.25 km spacing was then modeled around the three gathering centers, the three flow stations, and the Central Compressor Plant. A 0.5 km grid spacing was modeled around the Central Power Station and the area of maximum impact in the Deadhorse area identified in previous permit analyses for Prudhoe Bay Unit sources. As a result of these analyses the maximum predicted SO_2 and TSP concentrations from the proposed sources did not reach the 1 $\mu g/m^3$ significance levels. Therefore no further annual impact modeling was performed for SO_2 and TSP.

Annual NO_2 concentrations resulting from the proposed new sources were predicted to exceed significance levels and therefore ISCLT modeling runs were performed for all NO_x sources in the inventory (Appendix A) and for the 8 x 5 receptor grids examined in the significant impact analysis. From these runs, four areas of maximum impact were identified for more refined modeling. These "hot spots" were areas around Flow Station 1 and Gathering Centers 1, 2, and 3. In all cases maximum impacts were predicted to occur at receptors located 0.25 km from the facilities.

TABLE 6-1

RESULTS OF SCREENING MODELING ANALYSES FOR EMISSIONS FROM PROPOSED PRUDHOE BAY UNIT ADDITIONS ALONE

Pollutant	Averaging Time	Maximum Predicted Concentration ($\mu g/m^3$)	Significance Level* ($\mu g/m^3$)
SO_2	Annual	0.7	1
	24-hour	2.0	5
	3-hour	3.3	25
TSP	Annual	0.86	1
	24-hour	6.1	5
CO	8-hour	<113	500
	1-hour	113	2000

*As defined in 1977 Clean Air Act Amendments, Federal Register, June 19, 1978.

6.2.2 Short-Term

CO

CO emissions were modeled in the short-term PTPLU model for each of the 14 proposed new sources and for all stability classes (A through F). In this screening analysis the building wake effects option of PTPLU was used. The maximum concentrations predicted for each source were added together to determine a conservative total maximum 1-hour CO level for all sources. Maxima were summed without consideration given to differences in the wind speed and stability class associated with each individual maximum.

The worst-case 1-hour CO level calculated from this totalling of predicted maxima was about 110 $\mu g/m^3$. Since this highly conservative prediction is well below the 500 $\mu g/m^3$ and 2000 $\mu g/m^3$ significance levels established in the PSD regulations for 8-hour and 1-hour averaging periods, no further CO impact analyses were warranted.

SO_2 and TSP

Emissions of SO_2 and PM from the proposed new sources were input to the ISCST model to determine areas of short-term significant impact. This model was run in its rural mode with the building wake effects option selected. A polar coordinate receptor grid was centered around the original coordinates for Flow Station 1 and Gathering Center 2. These receptor areas were chosen because maximum SO_2 and PM emissions from the proposed Prudhoe Bay Unit sources will occur at these two facilities. Receptors were spaced at distances of 0.25, 0.5, 1.0, and 2.0 km from the origin along radials spaced 20 degrees apart.

The short-term impacts at all proposed new sources were examined in the ISCST for these two receptor areas. Modeling results show that maximum predicted 24-hour and 3-hour SO_2 concentrations fall well below the short-term significance levels defined in the PSD regulations. Therefore no further impact analyses for SO_2 were warranted.

Modeling results for TSP show that maximum predicted increases due to emissions from the proposed new Prudhoe Bay Unit sources will slightly exceed the significance level of 5 $\mu g/m^3$ just downwind of Flow Station 1 and Gathering Center 2. Therefore more refined modeling of 24-hour TSP impacts on the NAAQS and the PSD increments is necessary.

The results of the short-term screening analyses for CO, SO_2, and TSP are presented in Table 6-1.

Ozone

The impact of the emissions of proposed sources on ozone concentrations was projected using a reverse rollback technique. Existing ozone levels, less background concentrations, were compared to existing total hydrocarbon emissions to develop an empirical ratio between hydrocarbon emissions and ozone concentrations. This ratio was applied to the increased total hydrocarbon emissions generated by all sources that were not yet operating at the time the ambient air quality monitoring was performed to determine the expected increase in ozone concentrations. The existing contribution and the background were then added to this value to yield the total projected ozone concentration.

Maximum measured 1-hour ozone concentration	=	113 $\mu g/m^3$
Background ozone concentration	=	51 $\mu g/m^3$
Maximum contribution from existing sources	=	62 $\mu g/m^3$
Total hydrocarbon emissions from existing sources	=	1671 TPY
Total hydrocarbon emissions from previously permitted sources	=	2501 TPY
Total hydrocarbon emissions from proposed Prudhoe Bay Unit sources	=	269 TPY

Maximum estimated one-hour ozone concentrations:

$$\frac{(62\ \mu g/m^3)(2501\ \text{TPY} + 269\ \text{TPY})}{1671\ \text{TPY}} + 51 = 154\ \mu g/m^3$$

The maximum estimated 1-hour ozone level falls below the primary NAAQS for ozone of 235 $\mu g/m^3$.

The application of this methodology yields conservative results, that is, higher levels than would reasonably be expected. The extreme isolation of the site and the unique meteorology of the area would preclude the enhancement or generation of high ozone levels by the proposed facility. Problems associated with elevated ozone levels are commonly associated with large urban areas far away from the Prudhoe Bay area. Ozone formation and its subsequent build-up is dependent in part on hydrocarbon/nitrogen oxides ratios, solar radiation, humidity, and temperature (Revlett, 1977). The amount of ozone formed in the photochemical process is dependent not only on the absolute concentration of hydrocarbons and nitrogen oxides, but also on the ratios. It is reasonable to assume that the concentrations of these pollutants will be proportional to their emissions. The proposed sources will emit much larger quantities of NO_x than hydrocarbons. If NO_x levels are high and hydrocarbons low, little ozone is produced (Westberg, 1978). The high levels of NO inhibit the formation of ozone over long periods of time during which the NO is oxidized to NO_2 (Hecht, 1974).

Although a precise relationship between levels of NO_x and ozone can not be defined, quantitative estimates can be made of the relationship. One study (Miller, 1978) provides field confirmation of laboratory findings which indicate that when the hydrocarbon/NO_x ratio is less than 8/1, peak ozone levels are inversely proportional to the NO_x level. Since the increased NO_x emissions from the proposed Prudhoe Bay Unit sources will be larger than the hydrocarbon emissions, by about a factor of 30, the hydrocarbon/NO_x ratio is much less than the critical 8/1. Thus, it is not unreasonable to assume that peak ozone concentrations will decrease as the NO_x concentration increases.

A study of a large source of hydrocarbons (9000 TPY) showed a relatively small (less than 10 ppb, in plume) increase in ozone, and indicated that the emissions had a minimal effect on ambient oxidant levels (Westberg, 1978).

The extreme meteorological conditions of Prudhoe Bay also inhibit ozone formation. The intensity of solar radiation is an important parameter as it governs the photolysis rate of nitrogen dioxide, the reaction that initiates and sustains the oxidant formation process. With a maximum solar angle (elevation of sun with respect to the horizon) of approximately 45°, the light intensity at Prudhoe Bay is low, restricting ozone formation. The low temperatures and humidity which are common to the area also constrain the build-up of ozone.

6.3 Refined Modeling

6.3.1 Annual NO_2

NO_x emissions from all existing, permitting, and proposed sources were examined in a refined ISCLT modeling exercise to determine maximum impacts. The eight receptor grids discussed in Section 6.2 were modeled for two cases. The first case included all existing, previously permitted, and proposed sources except the proposed gas conditioning plant sources included in the Northwest Alaskan Pipeline permit application. The second case included the gas conditioning plant sources as well as all sources in the first case.

The ozone limiting method described by Cole and Summerhays (1979) and recommended in the 1980 draft EPA modeling guidelines was applied to determine maximum annual NO_2 levels from the predicted NO_x concentrations. Basically, this technique limits the formation of NO_2 to an in-stack conversion component and an atmospheric conversion component. The atmospheric component can not exceed the maximum predicted volumetric concentration of ozone. Maximum annual ozone concentrations were determined from existing and projected hydrocarbon emissions and existing measured annual average ozone levels using the reverse rollback technique discussed in Section 6.2.3. The calculations of maximum NO_2 concentrations for both cases are presented below:

Existing Concentrations

Maximum measured annual ozone concentration (Drill Site 9)	= 51 $\mu g/m^3$
Background ozone concentration (Drill Site 9)	= 51 $\mu g/m^3$

Maximum estimated contribution to ozone levels from existing sources = 0 $\mu g/m^3$

Maximum NO_2 background = 4 $\mu g/m^3$

Total Hydrocarbon Emissions (TPY)

	Case 1	Case 2
Existing Sources	1671	1671
Other Sources	1625	2770

Projected Ozone Concentrations with Reverse Rollback

Case 1: $51 + 0 + 0\left(\frac{1625}{1671}\right) = 51\ \mu g/m^3$

Case 2: $51 + 0 + 0\left(\frac{2770}{1671}\right) = 51\ \mu g/m^3$

Ozone Limited NO_2 Concentrations

Case 1: $(51)\left(\frac{NO_2 \text{ molecular wt}}{\text{Ozone molecular wt}}\right) =$

$(51)\left(\frac{46}{48}\right) = 49\ \mu g/m^3$

Case 2: $(51)\left(\frac{46}{48}\right) = 49\ \mu g/m^3$

Maximum NO_2 with Ozone Limiting

NO_2 = In-stack Term + Atmospheric term + Background

Case 1: $(0.10)(131.5) + 49 + 4 = 66.2\ \mu g/m^3$

Case 2: $(0.10)(133) + 49 + 4 = 66.3\ \mu g/m^3$

The results of this analysis are compared to the NAAQS for NO_2 in Table 6-2. Examination of this table shows that the total NO_x emissions from all sources, including the proposed

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TABLE 6-2
MAXIMUM PREDICTED ANNUAL
NO_2 CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Without Proposed Gas Conditioning Plant Sources Included**	Maximum Impact with Proposed Gas Conditioning Plant Sources Included	Primary and Secondary NAAQS
Background	4.0	4.0	
Prudhoe Bay Area Sources*	62.2	62.3	
TOTAL	66.2	66.3	100

*Includes all existing, previously permitted, and proposed sources.

**Sources for which permit application is being submitted by Northwest Alaskan Pipeline Company.

Northwest Alaskan Pipeline facilities should not result in a violation of the NAAQS for NO_2. The incremental increase in maximum annual NO_2 concentration due to the inclusion of the proposed Northwest Alaskan Pipeline Company gas conditioning plant sources should be only about 0.1 $\mu g/m^3$.

6.3.2 24-Hour TSP

Emissions of particulate matter from existing, previously permitted, and prcposed facilities were examined in a refined ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD increments. The initial screening analysis identified 24-hour periods during which TSP concentrations due to emissions from the Unit Owners' proposed sources were predicted to exceed the significance level. In the refined analysis seven by seven receptor grids with 0.1 kilometer grid spacings were modeled around the areas of maximum concentrations identified for these 24-hour periods. These receptor areas are located in the vicinities of Flow Station 1 and Gathering Center 2.

Two cases were examined. The first case included all existing, previously permitted, and proposed sources except the proposed gas conditioning plant sources included in the Northwest Alaskan Pipeline permit application. The second case included the gas conditioning plant sources as well as all sources in the first case. ISCST results for appropriate sources groupings were added together to determine either NAAQS compliance or PSD Class II increment consumption.

The results of this analysis are presented in Table 6-3. This table shows that maximum predicted TSP levels fall well below the concentrations permitted by the primary and secondary NAAQS and by the PSD Class II increment. The incremental increase due to the inclusion of the proposed Northwest Alaskan Pipeline Company gas conditioning plant sources is insignificant.

TABLE 6-3
MAXIMUM PREDICTED 24-HOUR
TSP CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Without Proposed Gas Conditioning Plant Sources Included*	Maximum Impact with Proposed Gas Conditioning Plant Sources Included
Background	11.0	11.0
Existing Sources	4.28	4.28
Permitted and Proposed Sources	20.27	20.27
Impact on PSD Class II Increment	20.27	20.27
Impact on NAAQS	35.55	35.55
Allowable 24-Hour Class II Increment	37	37
Primary 24-Hour NAAQS	260	260
Secondary 24-Hour NAAQS	150	150

*Sources for which permit application is being submitted by Northwest Alaskan Pipeline Company.

6.4 References for Section 6

Bowers, J. F., J. R. Bjorklund, and C. S. Cheney, Industrial Source Complex (ISC) Dispersion Model User's Guide Vol. 1 and 2. EPA Report No. EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1979.

Cole, H. S., and J. T. Summerhays, "A Review of Techniques Available for Estimating Short-Term NO_2 Concentrations," Journal of the Air Pollution Control Association, 29:8, 1979.

Hecht, T. A., and J. H. Seinfeld, "Further Development of a Generalized Kinetic Mechanism for Photochemical Smog," Environmental Science and Technology, 8:327, 1974.

Revlett, G. H., "Ozone Forecasting Using Empirical Modeling," Kenvirons, Inc., Frankfort, Kentucky, 1977.

Westberg, H., et al., "Contribution of the General Motors Automotive Painting Facility at Janesville, Wisconsin to Ambient Ozone Levels," General Motors Corporation, GM Technical Center, Warren, New Jersey, 1978.

7.0 ADDITIONAL IMPACT ANALYSES

7.1 Visibility Impacts

Particulate matter of small diameter or aerosols formed by the conversions of SO_2 and NO_x emissions to nitrates and sulfates could potentially cause some impairment to the visibility in the Prudhoe Bay area. However, the total increase in emissions of particulate matter of all size ranges should be only about 210 tons per year as a result of the proposed new sources. In addition maximum incremental increases in 24-hour and annual TSP concentrations should be about 6 $\mu g/m^3$ and less than 1 $\mu g/m^3$, respectively. Therefore, the emissions of additional particulates should not significantly impact visibility in the area.

Enhancement of fog and ice fog formation in the study area may result from the proposed plant plumes and exhausts from the associated additional vehicles and buildings. These additional fogs and ice fogs may result in an incremental reduction in visibility in the Prudhoe Bay area.

Meteorological observers at the Deadhorse Airport have noted enhanced fog and ice fog occurrence in the settlements and contractors' camps in the Deadhorse area. Weather forecasts in the winter sometimes include mention of ice fog development in the camps. These ice fogs have been observed to advect downwind from the camps, and according to meteorological observers, the Deadhorse Airport sometimes receives ice fog created or enhanced in development by the settlement immediately to the northeast.

Based on the most frequent wind directions shown on the annual wind roses for the Prudhoe Bay area (Figures 4-1 and 4-2) any significant incremental impairment of visibility by fog or ice fog resulting from the proposed new sources should be restricted primarily to the Prudhoe Bay oil field although enhanced visibility impairment may occur in the vicinity of the Deadhorse area and the ARCO Base Camp airstrip.

A thick haze is visible over the Arctic Ocean each spring (Kerr, 1979). Visibility aloft is often reduced from more than 100 kilometers to less than 10. The cause(s) of the Arctic haze is not certain, but long-range transport of sulfates generated from European industry is suspected. Some haze is likely to occur in the immediate Prudhoe Bay area as a result of the new facilities, but should not have a discernible effect on the widespread Arctic haze. The oil development on the North Slope was originally suspected of contributing to the Arctic haze, but is no longer considered to be a significant factor (Shaw, 1979). The haze has been reported since the 1950s, well before the oil development began. Vanadium and manganese are found in the haze particles, but are almost non-existent in fuel oils burned in Europe and the contiguous United States.

Emissions of sulfur dioxide and nitrogen oxides from the proposed sources may undergo some conversion to sulfates and nitrates. However, SO_2 emissions increases will be small and predicted increases in ambient SO_2 concentrations will be less than significant levels. Therefore, SO_2 emissions would not likely affect visibility in the Prudhoe Bay area.

Increased NO_2 concentrations will result from atmospheric conversion of NO to NO_2. However, the low existing ozone levels will prevent significant increases in NO_2 levels as a result of the proposed sources. Total predicted annual NO_2 contrations from all existing and proposed NO_x sources will fall well below the primary NAAQS of 100 $\mu g/m^3$. Therefore, the increase NO_x emissions would not significantly affect existing visibility patterns.

Incremental impacts on the frequency and severity of reduced visibility are likely to be insignificant compared to any impacts resulting from existing sources. Furthermore, the areas of major concern with respect to visibility impairment are the PSD Class I areas. No Class I PSD areas are located within 900 kilometers of the Prudhoe Bay area. Therefore, no impact on visibility in Class I areas is expected.

7.2 Soils and Vegetation Impacts

Soils act as a significant sink for SO_2, NO_2, and particulates, all of which are removed from the air and absorbed on the soil and plant surfaces. The rate of adsorption is dependent upon distance from the source, pollutant concentrations in the air, soil properties, density of vegetation cover, and prevailing hydrological and meteorological conditions.

The end products of soil sorption are nitrates and sulfates. Maximum predicted annual concentrations of NO_2 would reach about 66 $\mu g/m^3$. Increases in maximum annual and short-term concentrations for other pollutants would be insignificant or very small.

It appears that the quantities of nitrates, thus added to the soil and assimilated into soil-plant systems will be insignificant as compared with those normally present in these soils or transported. Thus, the amounts of pollutants added in the vicinity of Prudhoe Bay oil field should exert a negligible impact on the soils of the area.

There is currently no available information on the tolerance levels of high Arctic plants for the criteria air pollutants. The probable impacts of the prcposed sources can, however, be inferred from the tolerance levels determined for plants native to lower latitudes. Table 7-1 has been taken from Heck and Brandt (1977) and indicates the threshold level for acute toxicity to plants. Comparing the lower range for NO_2 effects on sensitive plant taxa, 3,000 $\mu g/m^3$; the predicted total annual NO_2 levels of about 66 $\mu g/m^3$ would indicate no acute effects could possibly be expected. Since predicted increases in ambient concentrations of other pollutants will be insignificant, these increases should have no adverse impact on local vegetation.

Chronic effects from long-term exposure may be extremely difficult to either define or quantify. Long-term (22 days) exposure to low-levels of NO_2 (950 $\mu g/m^3$) has been reported to result in reducted productivity of a sensitive plant species (Jacobson and Hill, 1970). The levels of pollutant tested by far exceed the expected concentrations resulting from around the proposed sources. Although chronic effects due to long-term exposure to extremely low levels of NO_x cannot be ruled out entirely; the possiblity of their occurrence is remote.

7.3 Impacts of Anticipated Induced Growth

It is anticipated that little if any increase in the work force will result from the operation of the additional equipment described in this application. Consequently, the proposed new sources are not expected to have significant pollutant impacts other than those discussed in Section 6.0 of this application.

TABLE 7-1

NITROGEN DIOXIDE: PROJECTED POLLUTANT CONCENTRATIONS FOR SHORT-TERM EXPOSURES THAT WILL PROVIDE ABOUT FIVE PERCENT INJURY TO VEGETATION GROWN UNDER SENSITIVE CONDITIONS[1]

Exposure Time (hours)	Concentrations Producing Five Percent Injury By Plant Susceptability Groupings: Sensitive Plants[2] ($\mu g/m^3$)	Intermediate Plants ($\mu g/m^3$)	Resistant Plants[3] ($\mu g/m^3$)
0.5	11,502 - 23,004	19,170 - 47,925	≥38,340
1.0	5,751 - 19,170	17,253 - 38,340	≥34,506
2.0	4,793 - 14,378	13,419 - 28,755	≥24,921
4.0	3,834 - 11,502	9,585 - 23,004	≥19,170
8.0	2,876 - 9,585	7,668 - 17,253	≥15, 336

[1]Heck and Brandt (1977)

[2]Example: nitrogen dioxide; alfalfa, barley, cotton, pine, and squash

[3]Example: nitrogen dioxide; corn, oak, cantaloupe

7.4 References for Section 7

Heck, W. W. and C. S. Brandt, "Effects on Biological Systems" Air Pollution, Vol. II, 3rd Edition, Edited by A. C. Stern, pp. 159-227, 1977.

Jacobson, J. S. and A. C. Hill, Recognition of Air Pollution Injury to Vegetation, Air Pollution Control Association, Pittsburgh, PA, 1970.

Kerr, Richard A., "Global Pollution: Is the Arctic Haze Actually Industrial Smog?", Science, Vol. 205, July 20, 1979, pp. 290-293.

Shaw, Glen, Personal Communications, August 1979, Geophysical Institute, University of Alaska, Fairbanks, Alaska.

APPENDIX A
EMISSIONS INVENTORIES

TABLE A-1

GROUP 1: EXISTING SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
ACT	ARCO P-357	449.50	7794.60	.434	.009	.019	.019	.032	.006	15.2	623	1.0	10.6
ACT	ARCO P-357	449.50	7794.60	.03	.005	.003	.003	.004	.001	15.2	623	.3	10.6
ACC	ARCO P-358	448.40	7794.70	2.7	.039	.117	.117	.198	.035	15.2	623	1.0	10.6
ACT	ARCO P-136	449.30	7794.40	1.33	.00	.116	.116	.00	.17	15.2	555	1.2	10.6
ACT	ARCO P-135	449.30	7794.40	.396	.113	.038	.038	.94	.706	10.7	1033	.9	6.9
FS-1	ARCO P-138	446.10	7795.10	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-1	ARCO P-138	445.90	7795.30	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
FS-2	ARCO P-381	449.55	7795.60	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-2	ARCO P-381	449.45	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
FS-3	ARCO P-443	440.75	7795.80	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-3	ARCO P-443	440.75	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
AFC	ARCO P-325	443.70	7802.20	.578	.00	.50	.50	.00	.076	16.1	611	.9	10.6
AFC	ARCO P-324	443.70	7802.20	164.0	2.12	5.58	5.58	45.70	16.7	25.8	755	2.4	50.6
AFC	ARCO P-324	443.70	7802.20	1.53	.022	.066	.066	.113	.02	9.1	519	1.1	10.6
CC-1	SOHIO P-338	435.80	7799.50	.037	.063	.176	.095	.25	.076	7.3	1088	.5	6.9
CC-1	SOHIO P-338	435.80	7799.50	.13	.064	.16	.086	.009	.032	7.3	1088	.5	7.4
CPS	SOHIO P-185	437.50	7797.20	109.2	1.403	3.70	3.70	30.30	11.4	15.8	777	2.7	50.6
CPS	SOHIO P-183	437.50	7797.20	20.31	.258	.69	.69	5.63	2.12	15.8	777	2.7	50.6
DW	DOW P-325	447.90	7792.00	1.25	.059	.044	.044	.767	.125	3.7	721	.2	15.2
DW	DOW P-325	447.90	7792.00	.078	.16	.067	.067	.006	.004	3.7	721	.2	7.4
N1	NANA P-413	447.30	7791.00	.76	.63	.011	.011	8.82	.377	20.0	450	.9	13.7
N1	NANA P-413	447.30	7791.00	.38	.32	.006	.006	4.41	.189	20.0	450	.9	7.4
PS1	ALY. P-289	439.00	7796.00	25.1	.320	.85	.85	6.99	2.55	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.04	.009	.035	.035	.289	.105	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.56	.022	.067	.067	.115	.02	13.7	623	1.0	10.7
PS1	ALY. P-289	439.00	7796.00	.00	.014	.001	.001	.00	.00	7.9	1144	.4	6.9
PS1	ALY. P-289	439.00	7796.00	.062	.01	.003	.003	.001	.002	7.9	1144	.4	7.4
N2	NANA P-423	444.40	7789.40	9.66	.64	.69	.69	2.09	.77	7.6	431	.5	18.3
N2	NANA P-434	444.40	7789.40	.04	.113	.707	.707	.904	.706	10.7	1032	.9	6.9
VE	VE P-482	446.00	7791.60	7.00	.47	.50	.39	1.51	.56	7.6	421	.5	15.2
VE	VE P-482	446.00	7791.60	.195	.055	.35	.35	.47	.35	10.6	1033	.9	6.9
AOC	ARCO OPS CR	449.80	7794.60	.26	.431	.047	.035	.153	.397	12.2	971	1.1	6.9
AOC	ARCO OPS CR	449.80	7794.60	.08	.038	.018	.014	.01	.043	12.2	1366	.8	7.4
SOC	SOHIO BOC	435.80	7799.50	.063	.034	.02	.02	.007	.008	12.2	1366	.5	6.9
SOC	SOHIO BOC	435.80	7799.50	.003	.052	.002	.00	.13	.404	12.2	1088	.5	7.4
SOC	SOHIO BOC	435.80	7799.50	.20	.53	.40	.009	6.91	1.14	6.7	660	.5	18.3

TABLE A-1 (Continued)

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
CC-2	SOHIO P-374	430.00	7803.50	.03	.047	.066	.066	.187	.056	12.2	1088	.5	6.9
CC-2	SOHIO P-347	430.00	7803.50	.106	.054	.041	.041	.009	.022	12.2	1088	.5	7.4
	DH. ARPRT	445.00	7789.00	15.67	1.14	1.12	1.12	3.38	1.25	10.7	428	.6	22.8
FC	FRONTIER	445.70	7791.20	7.83	.52	.56	.56	1.69	.63	10.7	428	.5	18.3
	ACC	427.00	7801.80	2.61	.17	.19	.19	.56	.21	10.7	428	.3	18.3
FC	Downtown	446.50	7791.20	13.06	.87	.93	.93	2.82	1.04	10.7	428	.6	15.2
CC-1	SOHIO GC1	434.75	7800.90	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-1	SOHIO GC1	434.60	7800.95	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CC-2	SOHIO GC2	429.95	7801.90	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-2	SOHIO GC2	430.05	7801.90	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CC-3	SOHIO GC3	436.65	7798.60	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-3	SOHIO GC3	436.60	7798.55	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CPS	SOHIO CPS	437.50	7797.20	.28	.005	.012	.012	.02	.004	18.0	506	.4	3.5

TABLE A-2

GROUP 2: UNIT OWNERS PSD 1 SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SOHIO GC2	430.10	7801.85	35.33	.295	1.20	1.20	9.00	3.58	16.7	470	1.71	60.0
SOHIO GC3	436.70	7798.50	8.80	.077	.30	.30	2.45	.90	16.7	755	2.69	35.0
SOHIO CPS	437.50	7797.20	35.90	.304	1.25	1.25	10.31	3.77	16.7	755	2.80	42.0

TABLE A-3

GROUP 3: UNIT OWNERS PWI/LPS/AL SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
GC-1	434.70	7800.90	5.20	.032	.115	.115	.95	.17	16.7	830	.88	50.0
GC-1	434.75	7801.00	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-1	434.65	7801.10	67.20	.410	1.67	1.67	12.54	2.27	16.7	470	1.71	50.0
GC-1	434.75	7801.10	2.04	.039	.115	.115	.20	.03	7.6	623	.94	10.6
GC-1	434.60	7801.05	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-1	434.65	7800.90	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.85	5.20	.032	.115	.115	.95	.17	16.7	830	.88	50.0
GC-2	430.00	7801.85	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-2	430.05	7801.80	126.52	.773	3.17	3.17	23.58	4.28	16.7	470	1.71	50.0
GC-2	429.95	7801.80	3.05	.058	.17	.17	.29	.05	7.6	623	.94	10.6
GC-2	430.00	7801.75	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.75	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.70	7798.45	5.20	.032	.12	.12	.95	.17	16.7	830	.88	50.0
GC-3	436.65	7798.50	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-3	436.80	7798.45	67.20	.410	1.67	1.67	12.54	2.27	16.7	470	1.71	50.0
GC-3	436.60	7798.45	2.01	.039	.115	.115	.20	.07	7.6	623	.94	10.6
GC-3	436.70	7798.40	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.75	7798.60	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
DRILL PAD E	437.10	7804.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD F	433.50	7804.40	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD G	435.00	7802.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD D	434.90	7799.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD H	430.90	7800.10	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD J	430.80	7803.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD M	426.40	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD N	428.10	7802.50	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD R	428.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Q	431.00	7801.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD S	423.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Y	431.20	7796.80	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3

TABLE A-3 (Continued)

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
DRILL PAD A	434.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD C	437.30	7799.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD X	437.00	7793.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD B	437.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
CCP	443.70	7802.20	18.58	.113	.46	.46	3.45	.63	16.7	470	1.71	50.0
CCP	443.70	7802.20	.63	.012	.03	.03	.06	.01	9.1	519	.5	14.1
FS-1	446.00	7795.25	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-1	446.00	7795.20	80.29	.490	1.84	1.84	14.96	2.73	16.7	470	1.71	50.0
FS-2	449.55	7795.50	107.05	.654	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-2	449.55	7795.40	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-2	449.45	7795.50	2.39	.046	.14	.14	.23	.04	15.0	530	.9	12.0
FS-3	440.75	7795.70	107.05	.654	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-3	440.65	7795.80	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7

TABLE A-4

GROUP 4: UNIT OWNERS WATERFLOOD SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SWT	SWTR TRT	443.00	7810.10	7.88	.151	.45	.45	.78	.14	28.0	530	1.4	12.0
SWT	SWTR TRT	443.00	7810.10	2.85	.055	.16	.16	.28	.05	28.0	530	1.0	12.0
IPE	E INJ PLT	445.50	7795.00	59.47	.363	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	435.00	7800.70	59.47	.363	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	435.00	7800.70	2.39	.046	.14	.14	.23	.04	15.0	530	.9	12.0
IPE	E INJ PLT	445.50	7795.00	2.39	.046	.14	.14	.23	.04	18.3	530	..9	12.0

TABLE A-5

GROUP 5: UNIT OWNERS ADDITIONAL SOURCES

EQUIPMENT EXCHANGE ANALYSIS

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SIPW	435.00	7800.70	11.9	.073	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPW	435.00	7800.70	18.0	.342	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
GC-2	429.95	7801.70	5.6	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.70	7798.55	5.6	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
STP	443.00	7810.10	7.2	.137	.41	.41	.68	.12	22.2	450	0.91	14.4
SIPE	445.50	7795.00	11.9	.073	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPE	445.50	7795.00	18.0	.342	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
SIPE	445.50	7795.00	18.6	.114	.45	.45	3.47	.63	22.2	450	1.77	29.9

TABLE A-6

GROUP 6: NORTHWEST ALASKAN PIPELINE PROPOSED

NON-UNIT SOURCES

	UTM (km)		NO_x		Particulate							
Map ID	East	North	Annual (g/s)	SO_2 (g/s)	Short Term (g/s)	Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
AGCF	443.13	7802.39	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.17	7802.20	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.12	7802.40	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.16	7802.21	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.30	7802.33	96.31	1.90	1.85	1.85	23.10	4.20	28.96	605.2	3.81	15.24
AGCF	443.38	7802.05	128.64	2.52	2.52	2.52	30.96	5.64	28.96	605.2	4.02	15.24
AGCF	443.31	7802.15	42.88	.84	.84	.84	10.32	1.88	28.96	605.2	4.02	15.24
AGCF	443.31	7802.11	16.47	.32	.32	.32	3.76	.66	28.96	781.3	2.84	15.24
AGCF	443.07	7802.24	79.29	1.56	1.53	1.53	19.08	3.48	28.96	605.2	4.47	15.24
AGCF	443.23	7801.97	3.51	.99	.45	.45	.48	.09	38.10	421.9	1.16	15.24
AGCF	443.22	7801.97	7.44	2.07	.93	.93	1.05	.19	38.10	449.7	1.74	15.24
AGCF	443.33	7802.21	6.51	1.83	.81	.81	.93	.17	38.10	421.9	1.58	15.24
AGCF	441.50	7802.40	.30	.012	.01	.01	.011	.002	28.96	421.9	0.53	15.24
AGCF	441.60	7802.30	.35	.05	.05	.05	.00	.00	28.96	421.9	0.15	3.05
AGCF	441.60	7802.40	1.42	.016	.05	.05	.58	.107	28.96	605.7	0.86	15.24
AGCF	439.50	7796.80	.16	.05	.05	.05	1.14	.20	28.96	605.7	0.49	15.24

TABLE A-7

GROUP 7: UNIT OWNERS PROPOSED ADDITIONAL SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
GC-1	434.70	7800.95	11.53	.068	.28	.28	2.08	.38	22.2	450	1.16	31.4
GC-1	434.65	7801.00	26.90	.159	.66	.66	4.85	.88	22.2	450	1.98	33.2
GC-2	430.05	7801.70	17.29	.102	.43	.43	3.12	.57	22.2	450	1.16	31.4
GC-2	430.10	7801.75	34.59	.204	.85	.85	6.24	1.13	22.2	450	1.98	33.2
GC-3	436.75	7798.50	5.76	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.80	7798.55	46.12	.272	1.13	1.13	8.32	1.51	22.2	450	1.98	33.2
IPW	435.00	7800.70	19.22	.113	.47	.47	3.47	.63	22.2	450	1.98	33.2
FS-1	446.00	7795.15	3.84	.023	.09	.09	.69	.13	22.2	450	1.16	31.4
FS-1	445.90	7795.10	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
FS-1	446.10	7795.30	27.67	.163	.68	.68	4.99	.91	22.2	450	1.98	33.2
FS-2	449.45	7795.40	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.70	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.60	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
SWT	443.00	7810.10	24.60	.145	.60	.60	4.44	.81	22.2	450	.76	29.0

APPENDIX B

EMISSIONS CALCULATIONS

APPENDIX B - EMISSIONS CALCULATIONS

Typical fuel composition supplied by SOHIO:

Component	Molecular Weight	Mole %	LHV (Btu/lb)[1]	LHV (Btu/ft^3)[2]
CO_2	44.01	12.0	0	0
N_2	28.016	0.7	0	0
CH_4	16.043	74.6	21,502	880.4
C_2H_6	30.07	6.5	20,416	1566.9
C_3H_8	44.097	3.4	19,929	2243.0
IC_4H_{10}	58.124	0.6	19,614	2909.8
NC_4H_{10}	58.124	1.1	19,665	2917.3
IC_5H_{12}	72.151	0.3	19,451	3582.0
NC_5H_{12}	72.151	0.4	19,499	3590.8
C_6H_{14}	86.178	0.4	19,391	4265.1

$$\begin{aligned}\text{LHV of fuel} &= (.746 \times 880.4) + .065 \times 1566.9) + .034 \times 2243.0) \\ &\quad + (.006 \times 2909.8) + (.011 \times 2917.3) + (.003 \times 3582.0) \\ &\quad + (.004 \times 3590.8) + (.004 \times 4265.1) \\ &= 926.6 \text{ Btu/ft}^3 \text{ fuel @ } 25°\text{C, 1 atm} \\ &= 914 \text{ Btu/ft}^3 \text{ @ } 70°\text{F, 1 atm}\end{aligned}$$

$$V = \frac{nRT}{P} = \frac{(1 \text{ lb mole})\ (1.314 \text{ atm ft}^3/\text{lb mole °K})\ (294.27°\text{K})}{1 \text{ atm}}$$

$$V = 386.6 \text{ std ft}^3/\text{lb mole fuel}$$

---

[1]Lower Heating Value from Perry's Chemical Engineers Handbook, 5th Edition, table 3-203.

[2]At 25°C

Now, looking at the combustion calculations for the fuel we get:

.746		1.492	.746		1.492	(moles)
CH_4	+	$2O_2$	CO_2	+	$2\ H_2O$	
.065		.228	.13		.195	
C_2H_6	+	$3.5O_2$	$2\ CO_2$	+	$3\ H_2O$	
.034		.170	.102		.136	
C_3H_8	+	$5O_2$	$3\ CO_2$	+	$4\ H_2O$	
.017		.111	.068		.085	
C_4H_{10}	+	$6.5O_2$	$4\ CO_2$	+	$5\ H_2O$	
.007		.056	.035		.042	
C_5H_{12}	+	$8O_2$	$5\ CO_2$	+	$6\ H_2O$	
.004		.038	.024		.028	
C_6H_{14}	+	$9.5O_2$	$6\ CO_2$	+	$7\ H_2O$	
.873		2.095	1.105		1.978	(mole totals)

From this we get:

O_2 needed = 2.095 moles/mole fuel

$N_2 = \frac{79}{21} \times 2.095 = 7.8812$ moles/mole fuel (air is 79% N_2, 21% O_2 by volume)

CO_2 formed = 1.105 moles/mole fuel

H_2O formed = 1.978 moles/mole fuel

So with complete combustion at 0% excess O the flue gas products are:

Component	mole/mole fuel	Stoichiometric flue gas, moles
CO_2	.12 (from fuel) + 1.105 =	1.225
N_2	.007 (from fuel) + 7.8812 =	7.8882
H_2O	1.978	1.978

With complete combustion and 15 percent excess O_2 in the flue gas, the total lb moles O_2 (dry) per lb mole of fuel, X, is calculated by the following equation:

$$\frac{X \text{ lb moles } O_2}{X \text{ moles } O_2 + 1.225 \text{ lb moles } CO_2 + (7.8882 + \frac{79}{21} X) \text{ lb moles } N_{22}} = .15$$

$$\frac{X}{9.1132 + 4.7619X} = .15$$

$$X = 4.7847 \frac{\text{lb moles } O_2}{\text{lb mole fuel}}$$

Therefore, the flue products (dry) are:

Component	lb moles/lb mole fuel
CO_2	1.225*
N_2	25.8878
O_2	4.7845
Total (dry)	31.8973

*Note, we ignore 0.03 percent CO_2 in the air.

FUEL RATES AND FLUE GAS RATES FOR EXAMPLE GAS TURBINES

Example Turbine (for calculations)	Rated hp	Heat Rate (Btu/hp-hr)	lb moles* Fuel/hp-hr	lb moles** Flue (dry)/hp-hr
Solar Saturn T-1001	1,050	12,348	.034013	1.08492
Ingersoll-Rand GT-22	4,250	9,430	.025975	0.82853
Ingersoll-Rand GT-52	15,900	9,365	.025796	0.82282
General Electric M5251	25,000	9,640	.026553	0.84697
General Electric M5262A	26,250	9,780	.026939	0.85928
General Electric M5332B	33,550	8,910	.024542	0.78282

$$\text{*lb moles fuel/hp-hr} = \frac{\text{Heat Rate (Btu/hp-hr)} \times \text{ft}^3 \text{ fuel}}{914 \text{ Btu}} \times \frac{\text{lb mole fuel}}{391.8 \text{ ft}^3 \text{ fuel}}$$

$$\text{**lb moles flue (dry)/hp-hr} = \frac{\text{lb moles flue (dry)}}{\text{lb mole fuel}} \times \frac{\text{lb moles fuel}}{\text{hp-hr}}$$

$$= 31.8973 \times \frac{\text{lb moles fuel}}{\text{hp-hr}}$$

NO_2 Emissions from Gas Turbines

NO_x flue gas concentration = 150 ppmv NO_2 in flue gas on a dry basis at 15 percent excess O_2.

$$\frac{\text{lb moles flue gas (dry)}}{\text{hp-hr}} = \frac{9800\ \text{Btu}}{\text{hp-hr}} \times \frac{\text{lb moles (fuel)}}{386.6\ \text{scf (fuel)}}$$

$$\times \frac{31.9\ \text{moles (flue gas)}}{\text{lb mole (fuel)}}$$

$$= 0.8847\ \frac{\text{lb moles fuel}}{\text{hp-hr}}$$

$$NO_x\ \text{emissions}\quad \frac{\text{lb}}{1000\ \text{hp-hr}} = 0.8847\ \frac{\text{lb moles flue (dry)}}{\text{hp-hr}}$$

$$\times \frac{.000150\ \text{lb moles}\ NO_2}{\text{lb mole flue gas}}$$

$$\times \frac{46.008\ \text{lb}\ NO_2}{\text{lb mole}} \times 1000$$

$$= 6.1\ \text{lbs/1000 hp-hr}$$

The NO_x emissions for the combustion turbines with a maximum heat rating of 9800 Btu/hp-hr proposed in this permit application were calculated based on an emission factor of 6.1 lb/1000 hp-hr, selected as conservative. The higher number in the table above.

HC Emissions from Gas Turbines*

Emission factor = 0.2 lb HC/1000 hp-hr from AP-42 p. 149, table 3.3.2-1

$$\text{Proposed turbine h.p.} \times \frac{0.2 \text{ lb HC}}{1000 \text{ hp-hr}} \times \frac{8760 \text{ hr}}{\text{yr}} \times \frac{\text{ton}}{2000 \text{ lb}} = \frac{\text{tons HC}}{\text{yr}}$$

Proposed Turbine, hp	Tons HC/yr
22,600	19.8

*Expressed as total hydrocarbons.

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CO Emissions from Gas Turbines

Emission factor = 1.1 lb CO/1000 hp·hr from AP-42 p. 149 table 3.3.2-1

$$\text{Proposed turbine h.p.} \times \frac{1.1 \text{ lb CO}}{1000 \text{ hp hr}} \times \frac{8670 \text{ hr}}{\text{yr}} \times \frac{\text{ton}}{2000 \text{ lb}} = \frac{\text{tons CO}}{\text{yr}}$$

Proposed Turbine, hp	Tons CO/yr
22,600	108.9

Particulate Emissions from Gas Turbines

Potential Emissions:

Emission factor = 14 lb/10^6 ft^3 gas burned, from AP-42, p. 146, table 3.3.1-2.

Assume turbine heat rate = 9800 Btu/hp-hr

$$\text{TSP emissions} = 14\ \text{lb TSP}/10^6\ \text{SCF}\left(\frac{\text{scf}}{914\ \text{Btu}}\right)\left(\frac{9800\ \text{Btu}}{\text{hp-hr}}\right) \times 1000$$

$$= 0.15\ \text{lb TSP}/1000\ \text{hp-hr}$$

Proposed Turbine, hp	Turbine TSP Emission Factor, lb/1000 hp-hr	Potential Tons Particulate/yr
22,600	0.15	14.8

SO_2 Emissions from Gas Turbines

Potential Emissions:

Assumptions:

1. H_2S content of fuel gas = 20 ppm
2. $H_2S + 3/2\ O_2 \rightarrow SO_2 + H_2O$
3. 1 mole H_2S = 1 mole SO_2
4. SO_2 = 20 ppm in fuel gas
5. Turbine heat rate = 9800 Btu/hp-hr
6. Standard conditions = 70°F, 1 atm.

$$\text{Turbine } SO_2 \text{ Emission factor} = \frac{20 \text{ lb moles } H_2S}{10^6 \text{ lb mole fuel}} \times \frac{1 \text{ lb mole } SO_2}{1 \text{ lb mole } H_2S}$$

$$\times \frac{64 \text{ lb } SO_2}{1 \text{ lb mole } SO_2} \times \frac{\text{lb mole fuel oil}}{386.6 \text{ scf fuel gas}}$$

$$\times \frac{\text{scf fuel gas}}{914 \text{ Btu}} \times \frac{9800 \text{ Btu}}{\text{hp-hr}}$$

$$= 0.036 \text{ lb } SO_2/1000 \text{ hp-hr}$$

Proposed Turbine, hp	Tons SO_2/yr
22,600	3.6

Emissions from Gas Heaters

The potential emissions of pollutants from gas heaters were calculated using the following equation:

$$\text{Annual emission rage, } \frac{\text{tons pollutant}}{\text{yr}} = \text{Heat rate of heater x}$$

$$\frac{\text{ft}^3\text{ fuel}}{\text{914 Btu}} \times \frac{\text{8760 hr}}{\text{yr}} \times \text{emission factor, } \frac{\text{lb pollutant}}{\text{1,000,000 ft}^3\text{ fuel burned}}$$

$$\times \frac{\text{ton}}{\text{2000 lb}}$$

Emission factors were taken from table 1.4-1 of AP-42. They are:

Particulates = 10 lb/10^6 ft^3 gas burned (av'g of 5-15)

CO = 17 lb/10^6 ft^3 gas burned

HC (as CH_4) = 3 lb/10^6 ft^3 gas burned

NO_x (as NO_2) = 176 lb/10^6 ft^3 gas burned (av'g of 120-230)

SO_2 Emissions from Gas Heaters

Potential Emissions:

Assumptions:

1. H_2S content of fuel gas = 20 ppm
2. $H_2S + 3/2\ O_2 \rightarrow SO_2 + H_2O$
3. 1 mole H_2S = 1 mole SO_2
4. SO_2 = 20 ppm in fuel gas
5. Heater = 125 MM Btu/hr
6. Standard conditions = 70°F, 1 atm.

$$\text{Heater } SO_2 \text{ Emission factor} = \frac{20 \text{ lb moles } H_2S}{10^6 \text{ lb mole fuel}} \times \frac{1 \text{ lb mole } SO_2}{1 \text{ lb mole } H_2S}$$

$$\times \frac{64 \text{ lb } SO_2}{1 \text{ lb mole } SO_2} \times \frac{\text{lb mole fuel gas}}{386.6 \text{ scf fuel gas}}$$

$$= 3.31 \text{ lb } SO_2/10^6 \text{ scf}$$

Proposed Heater, MM Btu/hr	Tons SO /yr
125	2.0

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APPENDIX C
METEOROLOGICAL DATA
PROCESSING

DATA SOURCES

Three sources of meteorological data were used to develop the annual Joint Frequency Function (JFF) and the modified short-term PREP data files for the modeling effort:

- Prudhoe Bay meteorological monitoring data,
- Barter Island National Weather Service (NWS) upper air data, and
- Prudhoe Bay acoustic sounder mixing heights for the winter night period.

Data for the period from April 1, 1979 through March 31, 1980 were processed according to the flow diagram shown in Figure C-1. The Prudhoe Bay monitoring data that were processed include 10-meter wind direction, wind speed, and temperature measurements from the Well Pad A site (Trailer 041) and 60-meter wind direction standard deviation measurements (σ_θ) from the Sohio Tower site (Site 039).

STABILITY CLASS DETERMINATION

Hourly stability class estimates were made according to the modified σ_θ method recommended in the Guideline on Air Quality Models, Proposed Revisions (EPA OAQPS Guideline Series, October 1980), with two exceptions:

- the σ_θ measurements from 60 meters were used, with a modification of the stability class limits to apply to 60 meters, since 10 meter σ_θ measurements were not available, and

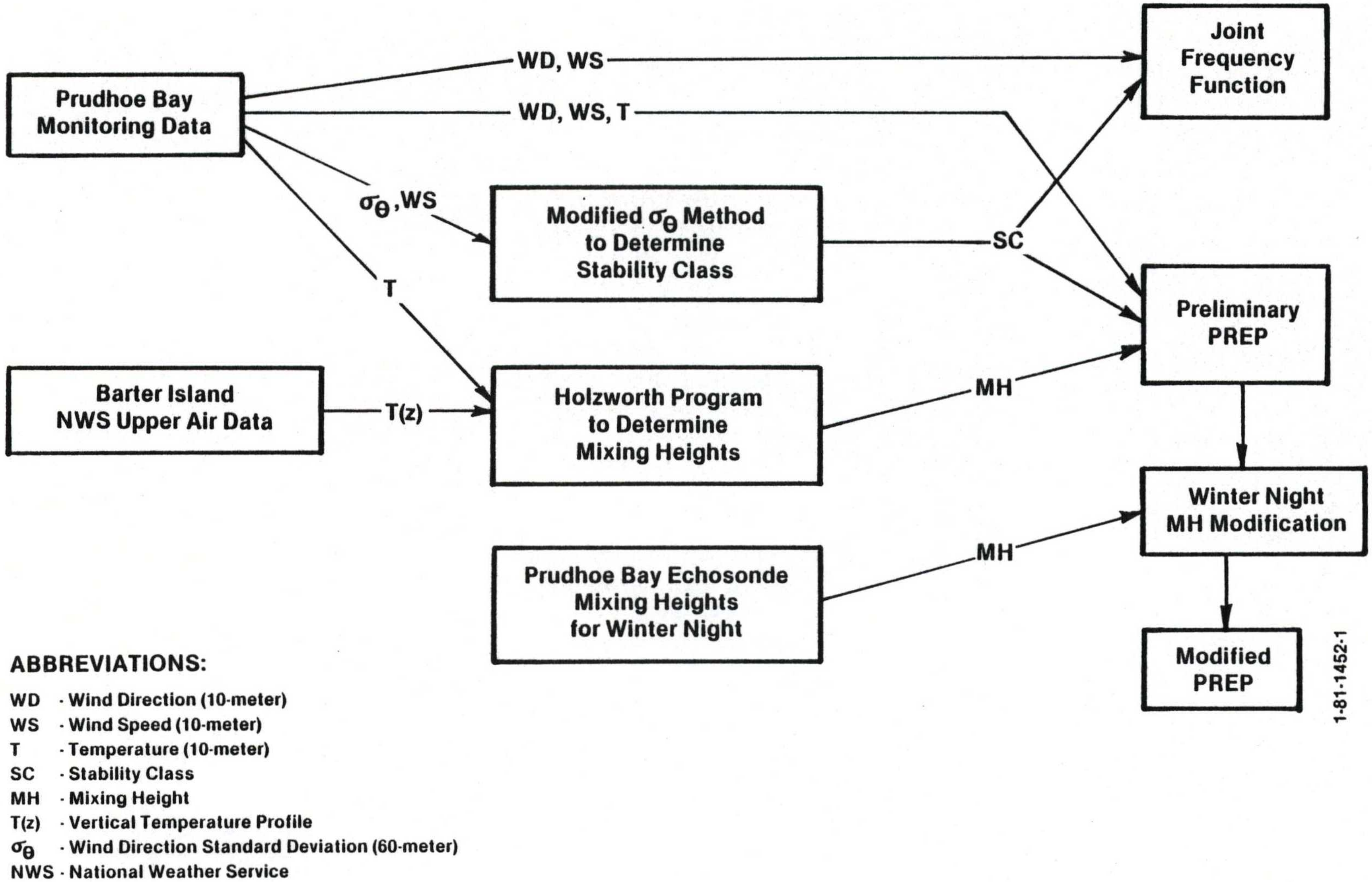

Figure C-1. Flow Diagram for Meteorological Data Processing.

- E and F stability class estimates that occurred when 10-meter wind speeds greater than 11 knots were changed to D stability.

The formula given by Sedefian and Bennett in "A Comparison of Turbulence Classification Schemes" (Atmospheric Environment, Vol. 14, pp. 741-750, 1980) was used to adjust the σ_θ stability class ranges, as follows:

$$\sigma_\theta(60\ \text{m}) = \sigma_\theta(10\ \text{m})\ (60/10)^{P_\theta}$$
$$= \sigma_\theta(10\ \text{m})\ 6^{P_\theta}$$

where P_θ = -0.06 for A stability
= -0.15 for B stability
= -0.17 for C stability
= -0.23 for D stability
= -0.38 for E stability
= -0.53 for F stability

Following this procedure, a new set of σ_θ stability class ranges was generated and used for the Prudhoe Bay applications:

Stability Class	Adjusted σ_θ Ranges for 60 Meters
A	$20.2° < \sigma_\theta$
B	$13.4° < \sigma_\theta \leq 20.2°$
C	$9.2° < \sigma_\theta \leq 13.4°$
D	$5.0° < \sigma_\theta \leq 9.2°$
E	$1.9° < \sigma_\theta \leq 5.0°$
F	$\sigma_\theta \leq 1.9°$

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The σ_θ values for 60 meters were modified to account for the surface roughness as recommended by the modeling guidelines. A roughness parameter of Z_o = 0.27 cm was used. This roughness value was determined from 40 and 60 meter wind speed observations at the SOHIO tower, using the logarithmic profile equation. Accordingly, the roughness modified

$$\sigma_\theta = \sigma_\theta\ (Z_o/15\ \text{cm})^{0.2} = 0.45\ \sigma_\theta.$$

The roughness modified σ_θ was used to determine the stability class from the table previously described.

For nighttime conditions (one hour prior to sunset to one hour after sunrise) adjustments to the stability class estimates were made according to the new modeling guidelines, as follow:

If the nighttime σ_θ stability class was	And if the 10m wind speed, u, was m/s	mi/hr	Then the stability class was changed to
A	$u<2.9$	$u<6.4$	F
	$2.9\leq u<3.6$	$6.4\leq u<7.9$	E
	$3.6\leq u$	$7.9\leq u$	D
B	$u<2.4$	$u<5.3$	F
	$2.4\leq u<3.0$	$5.3\leq u<6.6$	F
	$3.0\leq u$	$6.6\leq u$	D
C	$u<2.4$	$u<5.3$	E
	$2.4\leq u$	$5.3\leq u$	D
D	wind speed not considered		D
E	wind speed not considered		E
F	wind speed not considered		F

MIXING HEIGHT DETERMINATION

The Holzworth program from the National Climatic Center was used to compute twice-daily mixing heights based on the vertical temperature profiles from Barter Island in conjunction with 10-meter temperatures monitored at Prudhoe Bay. These twice daily mixing heights were input to the PREP preprocessor program to calculate hourly mixing heights for the one-year period. PREP was not designed to handle situations in which the meteorological data is collected at a monitoring site above the Arctic Circle. Therefore, PREP was modified to handle the impact of the circumpolar sun on processing meteorological data. These modifications are identical to those discussed in the Unit Owners' Waterflood Application.

Hourly mixing heights produced by the modified PREP program were used for the entire period except for October 2, 1979 through February 2, 1980 when the maximum daily sun elevation above the horizon was less than about 10 degrees. The PREP determination of mixing heights is not applicable to the winter nighttime conditions that occur at Prudhoe Bay because it assumes that unstable conditions occur each day due to solar heating. For the winter nighttime period, mixing height measurements made by an acoustic sounder at Prudhoe Bay were used. Only mixing heights identified with a capping elevated inversion were used in this case. For times during the winter period where a capping inversion was not present, the mixing height was considered to be undefined and an arbitrary, large volume of 5,000 meters was used.

The annual mixing height for long-term modeling was determined by averaging the Holzworth determined afternoon mixing heights. An annual average value of 300 meters was calculated.

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APPENDIX D
DISPERSION MODELS

ISC

The Industrial Source Complex (ISC) Gaussian dispersion model (Bowers et al, 1979) is a set of two computer programs that can be used to assess the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. The short-term version of ISC is ISCST and is used to predict short-term ambient concentrations. The long-term version of ISC is ISCLT and is used to predict annual or seasonal average ambient concentrations. The ISC model is designed for use with non-reactive pollutants. ISC is a multiple source model capable of predicting the interactive impacts of groups of sources under either rural or urban conditions and in flat or gently rolling terrain. Sources can be either point sources, volume sources, or area sources.

Briggs' plume rise formulas (Briggs, 1971, 1975) are incorporated into ISC and allow for the computation of distance-dependent and final plume rise for both buoyancy and momentum dominated plumes. In addition, ISC accounts for the effects of stack tip aerodynamic downwash and the effects of aerodynamic wakes and eddies formed by buildings and other structures on plume dispersion (Huber and Snyder, 1976) (Huber, 1977).

The ISC dispersion model is designed to calculate the effects of gravitational setting and dry deposition for plumes containing particulate matter and dry deposition for plumes containing gaseous pollutants. Alternately, the ISC model can calculate total dry deposition in lieu of ambient concentrations. A wind-profile exponent law is used to adjust the observed wind speed from the measurement height to the physical emission height for plume rise and concentration calculations. The Pasquill-Gifford curves (Turner, 1970) are used to calculate lateral (σ_y) and vertical (σ_z) plume spread.

The ISCST model uses sequential hourly inputs of ambient temperature, wind speed, wind direction, stability class, and mixing height to compute concentration or deposition values for averaging periods from 1 to 24 hours. If used with a season or year of sequential hourly meteorological data, ISCST will calculate seasonal or annual concentrations or depositions.

The ISCLT model uses a seasonal or annual statistical summary of meteorological information in the form of a joint frequency distribution of wind speed, wind direction, and stability class as meteorological input. Both seasonal and annual concentration or deposition calculations can be made with ISCLT.

PTPLU

PTPLU is a short-term Gaussian dispersion model designed to predict maximum hourly concentrations as a function of wind speed and stability for point sources located in areas of flat terrain. PTPLU is an updated version of the PTMAX Gaussian dispersion model (Turner and Busse, 1973).

A separate analysis is made for each individual stack. Input to the program consists of the source emission rate, physical stack height, and stack gas temperature. Also required are the stack gas volume flow or both the stack gas velocity and inside diameter at the top of the stack. Additional inputs to the model include the height at which the meteorological data is valid and the power law exponents used to adjust the wind speed to that expected at the physical stack height.

PTPLU determines, for each wind speed and stability class, either the final or distance-dependent plume rise using methods suggested by Briggs (Briggs, 1971, 1975). This plume rise is added to the physical stack height to determine the effective height of emissions. The effective height is used to determine both the maximum concentration and the distance to maximum concentration. The plume rise calculated by PTPLU can take into account stack tip downwash, buoyancy induced dispersion, and the effects of both buoyancy and momentum on plume rise. The Pasquill-Gifford horizontal and vertical dispersion coefficients as reported by Turner (Turner, 1970) are incorporated into the model.

REFERENCES FOR APPENDIX D

Bowers, J. F., J. R. Bjorklund, and C. S. Cheney, Industrial Source Complex (ISC) Dispersion Model User's Guide Vol. 1 and 2. EPA Report No. EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1979.

Briggs, G. A., Some recent analyses of plume rise observations, In Proceedings of the Second International Clean Air Congress, Academic Press, New York, 1971.

Briggs, G. A., Plume rise predictions. In Lectures on Air Pollution and Environmental Impact Analysis, American Meteorological Society, Boston, Massachusetts, 1975.

Huber, A. H. and W. H. Snyder, Building wake effects on short stack effluents. Preprint Volume for the Third Symposium on Atmospheric Diffusion and Air Quality, American Meteorological Society, Boston, Massachusetts, 1977.

Turner, D. B., 1970, Workbook of Atmospheric Dispersion Estimates. PHS Publication No. 999-AP-26, U.S. Department of Health, Education and Welfare, National Air Pollution Control Administration, Cincinnati, Ohio, 1970.

Turner, D.B. and A. Busse, User's guide to the interactive versions of three point source dispersion programs: PTMAX, PTDIS and PTMPT. Draft EPA Report, Meteorological Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1973.

APPENDIX E
JOINT FREQUENCY DISTRIBUTION
OF WIND SPEED, WIND DIRECTION
AND STABILITY CLASS
FOR PRUDHOE BAY AREA
(April 1, 1979-March 31, 1980)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000469	.000000	.000000	.000117	.000000	.000000	.000585
NNE	.000234	.000117	.000000	.000000	.000000	.000000	.000352
NE	.000352	.000352	.000117	.000117	.000000	.000000	.000938
ENE	.000117	.000352	.000117	.000000	.000000	.000000	.000586
E	.000117	.000000	.000117	.000000	.000000	.000000	.000234
ESE	.000352	.000117	.000117	.000000	.000000	.000000	.000585
SE	.000000	.000117	.000000	.000000	.000000	.000000	.000117
SSE	.000000	.000234	.000000	.000000	.000000	.000000	.000234
S	.000000	.000117	.000352	.000234	.000000	.000000	.000703
SSW	.000000	.000117	.000000	.000000	.000000	.000000	.000117
SW	.000352	.000234	.000117	.000117	.000000	.000000	.000821
WSW	.000000	.000117	.000117	.000000	.000117	.000000	.000352
W	.000117	.000117	.000000	.000117	.000000	.000000	.000352
WNW	.000117	.000469	.000117	.000000	.000000	.000000	.000703
NW	.000469	.000117	.000000	.000000	.000000	.000000	.000585
NNW	.000234	.000000	.000117	.000000	.000000	.000000	.000352
TOTAL	.002931	.002579	.001290	.000703	.000117	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF A STABILITY = .007620
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH A STABILITY = .000000

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ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000352	.000117	.000000	.000117	.000000	.000000	.000585
NNE	.000234	.000117	.000000	.000000	.000000	.000000	.000352
NE	.000117	.000234	.000117	.000000	.000000	.000000	.000469
ENE	.000000	.000117	.000000	.000000	.000000	.000000	.000117
E	.000234	.000117	.000117	.000234	.000000	.000000	.000703
ESE	.000117	.000000	.000469	.000117	.000000	.000000	.000703
SE	.000000	.000469	.000117	.000000	.000000	.000000	.000585
SSE	.000000	.000117	.000000	.000000	.000000	.000000	.000117
S	.000352	.000000	.000000	.000000	.000000	.000000	.000352
SSW	.000117	.000000	.000234	.000000	.000000	.000000	.000352
SW	.000000	.000234	.000000	.000000	.000000	.000000	.000234
WSW	.000000	.000117	.000000	.000000	.000000	.000000	.000117
W	.000234	.000234	.000000	.000000	.000000	.000000	.000469
WNW	.000117	.000117	.000117	.000000	.000000	.000000	.000352
NW	.000117	.000117	.000117	.000000	.000000	.000000	.000352
NNW	.000234	.000234	.000000	.000000	.000000	.000000	.000469
TOTAL	.002227	.002345	.001290	.000469	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF B STABILITY = .006331
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH B STABILITY = .000000

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ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000586	.001055	.000234	.000117	.000000	.000000	.001993
NNE	.000352	.001055	.000000	.000000	.000000	.000000	.001407
NE	.000234	.000469	.000117	.000000	.000000	.000000	.000821
ENE	.000117	.000469	.000234	.000000	.000000	.000000	.000821
E	.000234	.000469	.000117	.000000	.000000	.000000	.000821
ESE	.000117	.000352	.000000	.000000	.000000	.000000	.000469
SE	.000234	.000000	.000469	.000000	.000000	.000000	.000703
SSE	.000000	.000000	.000234	.000000	.000000	.000000	.000234
S	.000234	.000234	.000117	.000000	.000000	.000000	.000586
SSW	.000234	.000234	.000000	.000000	.000000	.000000	.000469
SW	.000117	.000703	.000234	.000000	.000000	.000000	.001055
WSW	.000000	.000234	.000000	.000000	.000000	.000000	.000234
W	.000117	.000117	.000234	.000000	.000000	.000000	.000469
WNW	.000352	.000000	.000234	.000000	.000000	.000000	.000586
NW	.000117	.000117	.000117	.000117	.000000	.000000	.000469
NNW	.000234	.000352	.000117	.000000	.000000	.000000	.000703
TOTAL	.003283	.005862	.002462	.000234	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = .011841
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = .000000

E-4

CORPORATION

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.001067	.005275	.002345	.001407	.000000	.000000	.010094
NNE	.000476	.003634	.002345	.004455	.000117	.000000	.011027
NE	.000831	.004689	.007034	.022978	.003986	.001055	.040573
ENE	.000709	.002579	.009379	.063892	.039977	.025557	.142093
E	.000242	.003634	.009027	.056038	.036225	.044666	.149831
ESE	.000945	.003165	.004807	.013365	.005041	.000938	.028261
SE	.000827	.002462	.002579	.001524	.000000	.000000	.007392
SSE	.001179	.002227	.001524	.001641	.000000	.000000	.006571
S	.000944	.002462	.001758	.000938	.000000	.000000	.006102
SSW	.001061	.002227	.005862	.007737	.000000	.000000	.016888
SW	.000594	.003751	.005393	.024267	.005862	.002462	.042329
WSW	.000944	.002579	.005744	.037397	.012896	.012192	.071753
W	.000945	.003048	.005862	.019461	.006565	.007620	.043501
WNW	.000356	.002110	.002814	.009144	.001876	.000703	.017003
NW	.000475	.003048	.002462	.002345	.000000	.000000	.008330
NNW	.001300	.004338	.002931	.001290	.000000	.000000	.009859
TOTAL	.012896	.051231	.071864	.267878	.112544	.095193	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = .611606
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = .000117

RADIAN CORPORATION

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000497	.002696	.004572	.000000	.000000	.000000	.007765
NNE	.001097	.003751	.004572	.000000	.000000	.000000	.009421
NE	.001271	.010082	.013834	.000000	.000000	.000000	.025186
ENE	.001472	.006096	.015709	.000000	.000000	.000000	.023278
E	.001144	.009144	.011137	.000000	.000000	.000000	.021425
ESE	.001825	.005862	.007268	.000000	.000000	.000000	.014955
SE	.001211	.003283	.002579	.000000	.000000	.000000	.007073
SSE	.000485	.001407	.000938	.000000	.000000	.000000	.002830
S	.001085	.002345	.001524	.000000	.000000	.000000	.004954
SSW	.001208	.002931	.005744	.000000	.000000	.000000	.009883
SW	.001479	.006800	.007855	.000000	.000000	.000000	.016133
WSW	.001351	.005744	.007034	.000000	.000000	.000000	.014129
W	.001227	.005041	.008089	.000000	.000000	.000000	.014357
WNW	.001463	.005041	.006213	.000000	.000000	.000000	.012718
NW	.000972	.002931	.003400	.000000	.000000	.000000	.007302
NNW	.000971	.002814	.002814	.000000	.000000	.000000	.006598
TOTAL	.018757	.075967	.103282	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF E STABILITY = .198007
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH E STABILITY = .000821

RADIAN CORPORATION

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000986	.001641	.001993	.000000	.000000	.000000	.004620
NNE	.001345	.001641	.002579	.000000	.000000	.000000	.005565
NE	.002256	.006213	.016178	.000000	.000000	.000000	.024658
ENE	.001550	.006213	.014537	.000000	.000000	.000000	.022300
E	.002127	.005158	.014654	.000000	.000000	.000000	.021939
ESE	.000997	.002227	.005041	.000000	.000000	.000000	.008266
SE	.000613	.000821	.001407	.000000	.000000	.000000	.002840
SSE	.000604	.000352	.000234	.000000	.000000	.000000	.001190
S	.000482	.000234	.000469	.000000	.000000	.000000	.001185
SSW	.000495	.000938	.003751	.000000	.000000	.000000	.005185
SW	.001293	.005275	.014771	.000000	.000000	.000000	.021340
WSW	.000904	.003634	.015240	.000000	.000000	.000000	.019779
W	.001382	.003634	.012661	.000000	.000000	.000000	.017677
WNW	.000860	.001290	.001993	.000000	.000000	.000000	.004143
NW	.000482	.000234	.000938	.000000	.000000	.000000	.001654
NNW	.000613	.000821	.000821	.000000	.000000	.000000	.002254
TOTAL	.016999	.040328	.107268	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF F STABILITY = .164596
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH F STABILITY = .001055

RADIAN CORPORATION

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.003994	.010785	.009144	.001758	.000000	.000000	.025682
NNE	.003753	.010317	.009496	.004455	.000117	.000000	.028138
NE	.005036	.022040	.037397	.023095	.003986	.001055	.092609
ENE	.003919	.015826	.039977	.063892	.039977	.025557	.189147
E	.004060	.018523	.035170	.056272	.036225	.044666	.194916
ESE	.004357	.011723	.017702	.013482	.005041	.000938	.053243
SE	.002899	.007151	.007151	.001524	.000000	.000000	.018725
SSE	.002283	.004338	.002931	.001641	.000000	.000000	.011193
S	.003120	.005393	.004220	.001172	.000000	.000000	.013906
SSW	.003129	.006448	.015592	.007737	.000000	.000000	.032906
SW	.003810	.016999	.028370	.024385	.005862	.002462	.081888
WSW	.003180	.012427	.028136	.037397	.013013	.012192	.106345
W	.004006	.012192	.026846	.019578	.006565	.007620	.076808
WNW	.003269	.009027	.011489	.009144	.001876	.000703	.035509
NW	.002657	.006565	.007034	.002462	.000000	.000000	.018718
NNW	.003620	.008558	.006800	.001290	.000000	.000000	.020267
TOTAL	.057093	.178312	.287456	.269284	.112661	.095193	

TOTAL RELATIVE FREQUENCY OF OBSERVATIONS = 1.000000
TOTAL RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE = .001993

RADIAN CORPORATION

APPENDIX F

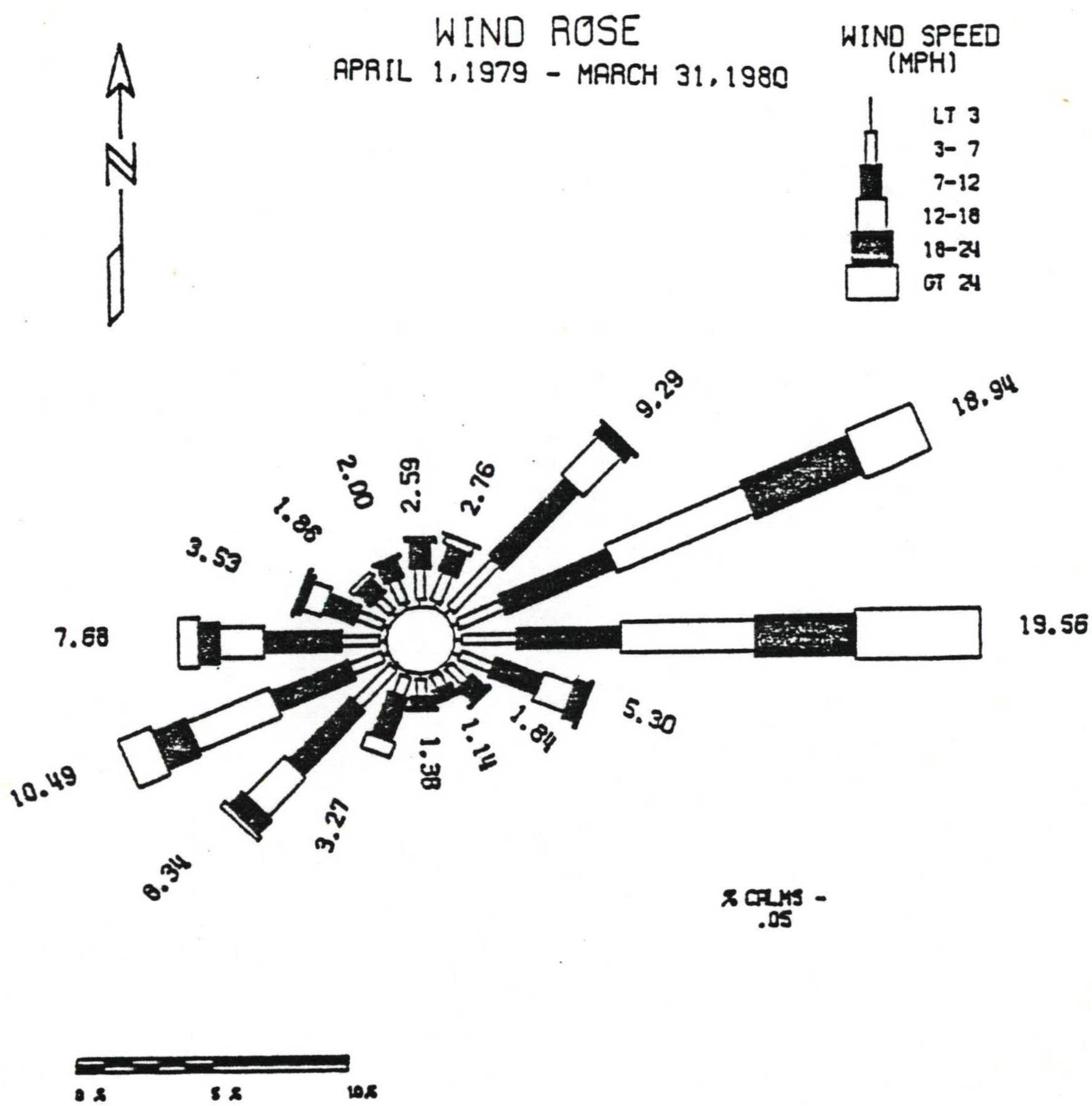
REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

Wind directions and windspeeds used in modeling were those measured at Site 1. A wind rose (joint frequency diagram) for these data is presented in Figure F-1. For comparison purposes, wind roses for Barter Island (1958-1964), the Deadhorse Airport (1976), and Barter Island (1968-1977), are presented in Figures F-2 and F-3. The similarity of wind patterns indicated for these geographically separated locations and different time periods strongly suggests that the Prudhoe Bay Site 1 data are representative of regional climatic conditions.

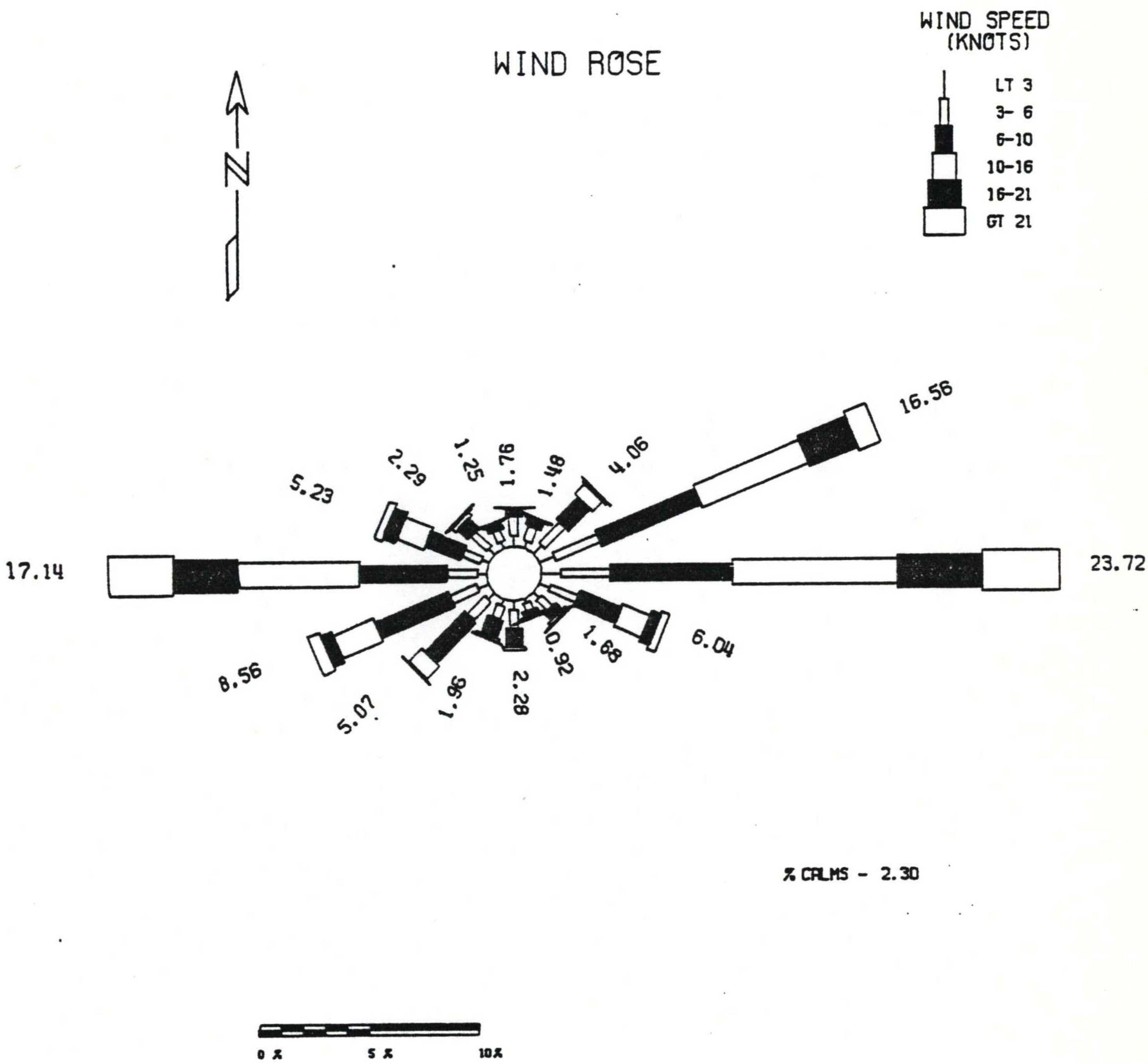
Stability class distributions for the Prudhoe Bay Monitoring Network, derived as described in Appendix C, are compared with those for Barter Island (1968-1977), which are derived by the Pasquill-Turner method, in Table F-1. When considering the differences in the bases for the stability classifications, it is concluded that the stability data from the Prudhoe Bay Network are reasonable approximations of regional conditions.

Precipitation and temperature data comparisons also indicate that the data measured at the Prudhoe Bay Monitoring Network, and used in the modeling analyses, are representative of the area. Precipitation data recorded during the April, 1979 to March, 1980 period at Point Barrow (3.19 inches) and Barter Island (7.20 inches) indicate a trend of increasing precipitation from west to east along the north coast of Alaska. The data for Prudhoe Bay (Site 2) for this time period (5.34 inches) is in close agreement with this trend. Temperature data recorded at the three 10-meter temperature sensors in the Prudhoe Bay Monitoring Network averaged 12.4°F. The mean annual temperature at Prudhoe Bay Airport during 1971-1973 was 7.9°F. The mean temperature at Point Barrow during the April 1979 to March 1980 period was 3.1°F higher than the climatological normal temperature established from 1941-1979; at Barter Island during the same period, the departure from the 1947-1970 climatological normal temperature was 3.3°F. This may be indicative of regional climatological change. When this difference from long-term mean temperature is considered in conjunction with the difference between 1.8-meter and 10-meter temperatures at Site 2 during the period of simultaneous measurements (more than 1°F), the Prudhoe Bay Monitoring Network data appear to be in close agreement with that expected at the Prudhoe Bay Airport.



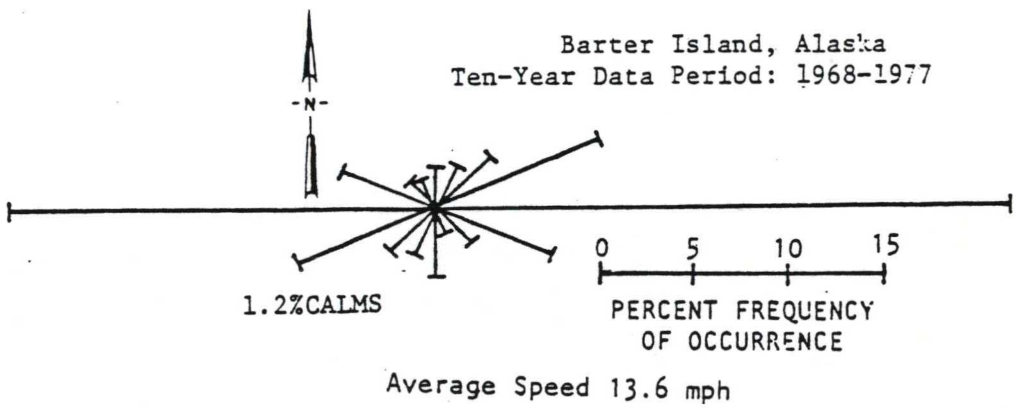
PRUDHOE BAY - DRILL PAD A

Figure F-1



BARTER ISLAND, ALASKA - ANN - 1958-1964

Figure F-2



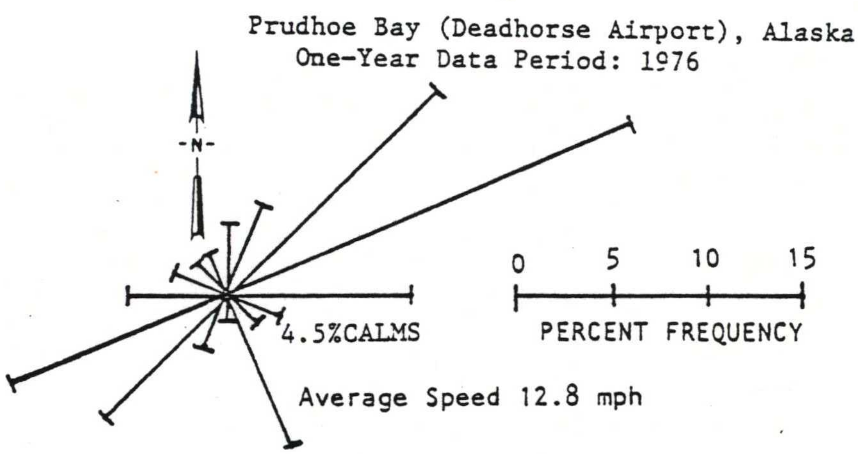


Figure F-3. Annual Wind Roses

TABLE F-1. ANNUAL FREQUENCY DISTRIBUTIONS OF PASQUILL STABILITY CLASSES WITH AVERAGE WIND SPEED BY STABILITY CLASS

		Barter Island (1968-1977)		Prudhoe Bay (1979-1980)	
Stability Class	Definition	Annual Frequency (percent)	Average Wind Speed (mph)	Annual Frequency (percent)	Average Wind Speed (mph)
A	Extremely Unstable	0.00	N/A	0.76	5.5
B	Unstable	0.86	4.7	0.63	5.3
C	Slightly Unstable	4.54	6.3	1.18	5.1
D	Neutral	79.54	13.4	61.16	14.8
E	Slightly Stable	9.36	7.9	19.80	6.4
F	Stable to Extremely Stable	5.70	3.6	16.46	6.9

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